Human Space Exploration by Antony Jeevarajan

Abstract

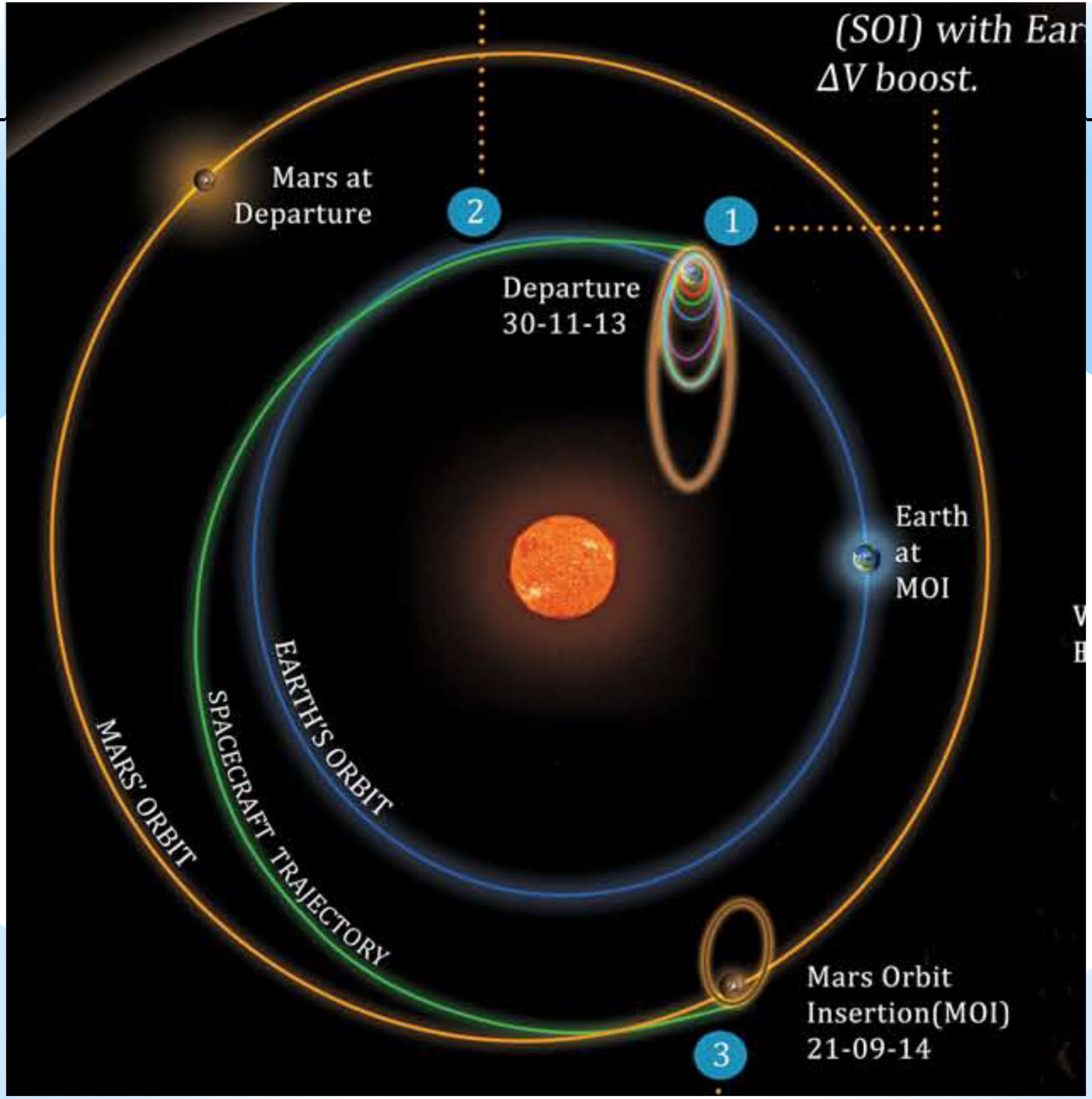
The Mars probe, launched by India a few months ago, is on its way to Mars. At this juncture, it is appropriate to talk about the opportunities presented to us for the Human Exploration of Mars. I am planning to highlight some of the challenges to take humans to Mars, descend, land, stay, ascend and return home safely. The logistics of carrying the necessary accessories to stay at Mars will be delivered in multiple stages using robotic missions. The primary ingredients for human survival is air, water, food and shelter and the necessity to recycle the primary ingredients will be articulated. Humans have to travel beyond the van Allen radiation belt under microgravity condition during this inter-planetary travel for about 6 months minimum one way. The deconditioning of human system under microgravity conditions and protection of humans from Galactic cosmic radiation during the travel should be taken into consideration. The multi-disciplinary effort to keep the humans safe and functional during this journey will be addressed.

Human Space Exploration

Antony Jeevarajan, Ph.D.
Johnson Space Center
National Aeronautics and Space Administration
Houston, TX 77058
Email: antony.s.jeevarajan@nasa.gov

India's Mars Mission

A. Jeevarajan/NASA


(SOI) with Ear
ΔV boost.
Mars at
Departure
2
1
Departure
30-11-13
Earth
at
MOI
EARTH'S ORBIT
SPACECRAFT TRAJECTORY
MARS' ORBIT
Mars Orbit
Insertion(MOI)
21-09-14
3

Mars Mission Exploration Tools

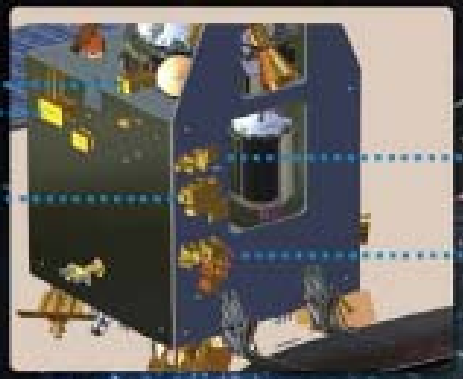
Lyman Alpha Photometer (LAP)

Lyman Alpha Photometer (LAP) is an absorption cell photometer. It measures the relative abundance of deuterium and hydrogen from Lyman-alpha emission in the Martian upper atmosphere (typically Exosphere and exobase). Measurement of D/H (Deuterium to Hydrogen abundance Ratio) allows us to understand especially the loss process of water from the planet.

Methane Sensor for Mars (MSM)

MSM is designed to measure Methane (CH_4) in the Martian atmosphere with PPB accuracy and map its sources. Data is acquired only over illuminated scene as the sensor measures reflected solar radiation. Methane concentration in the Martian atmosphere undergoes spatial and temporal variations.

Atmospheric studies



Mars Exospheric Neutral Composition Analyser (MENCA)

MENCA is a quadruple mass spectrometer capable of analysing the neutral composition in the range of 1 to 300 amu with unit mass resolution. The heritage of this payload is from Chandra's Altitudinal Composition Explorer (CHACE) payload

Particle environment studies

Mars Color Camera (MCC)

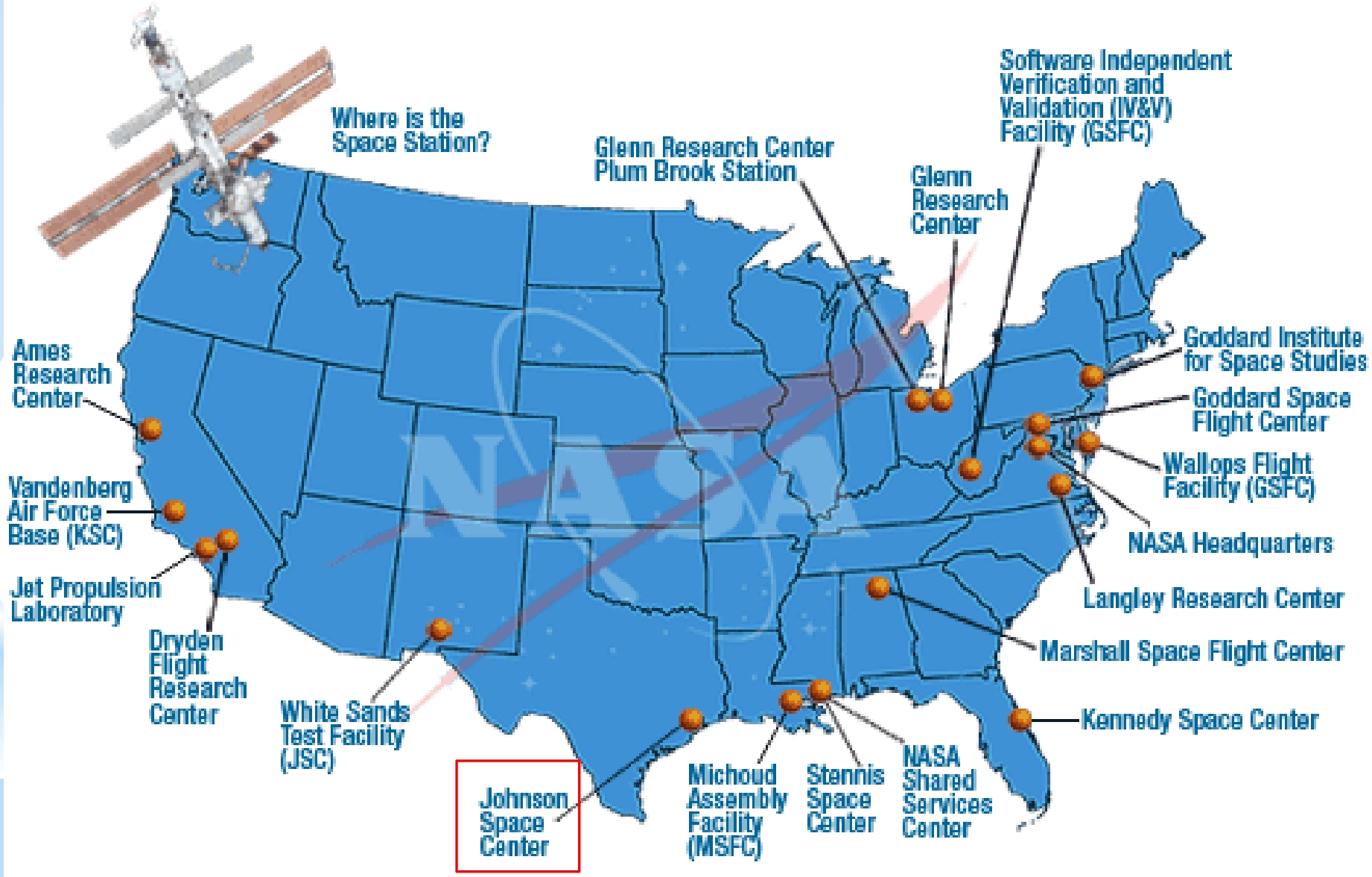
This tri-color Mars Color camera gives images & information about the surface features and composition of Martian surface. They are useful to monitor the dynamic events and weather of Mars. MCC will also be used for probing the two satellites of Mars – Phobos & Deimos. It also provides the context information for other science payloads.

Thermal Infrared Imaging Spectrometer (TIS)

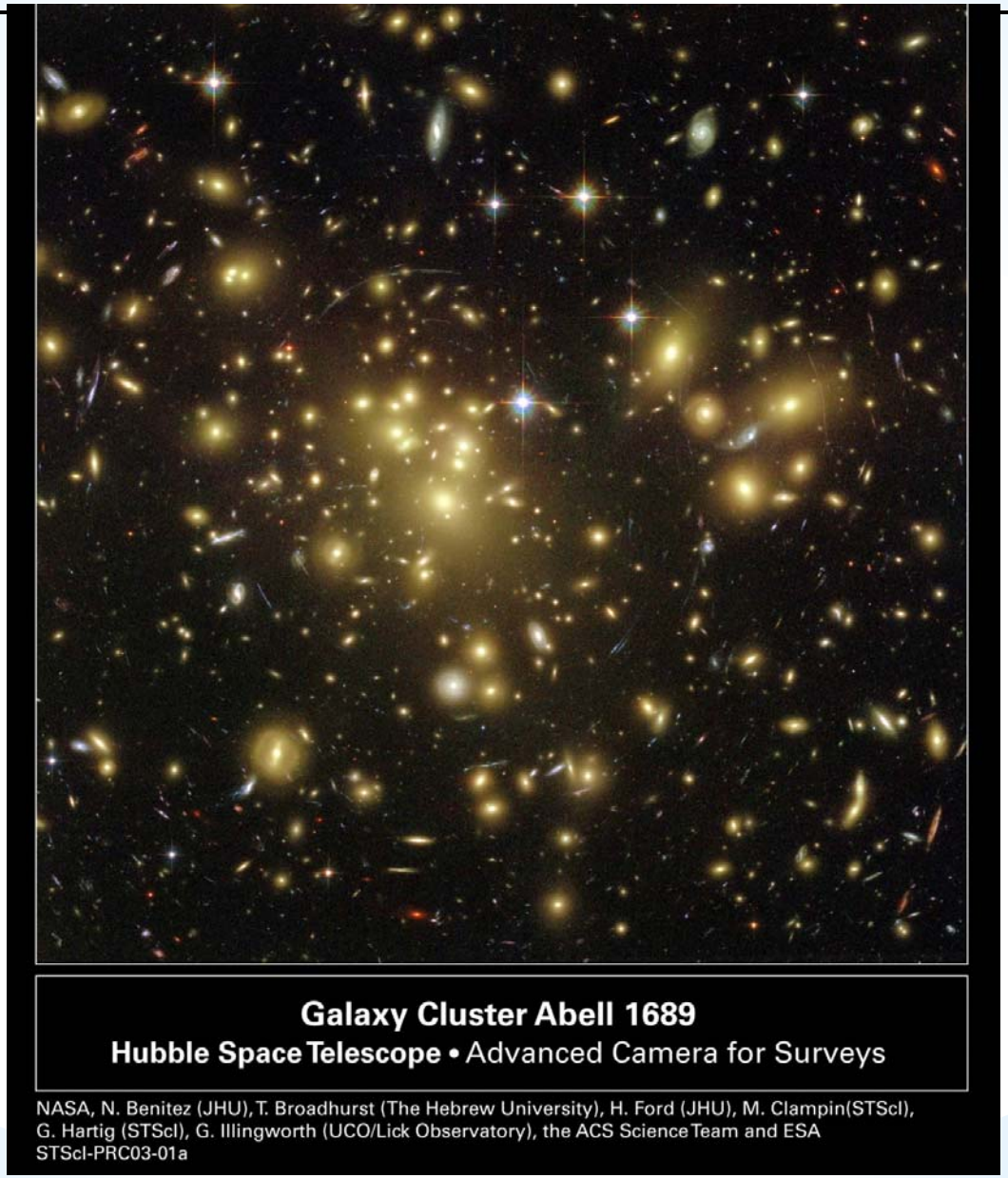
TIS measure the thermal emission and can be operated during both day and night. Temperature and emissivity are the two basic physical parameters estimated from thermal emission measurement. Many minerals and soil types have characteristic spectra in TIR region. TIS can map surface composition and mineralogy of Mars.

Surface Imaging Studies

NASA Centers

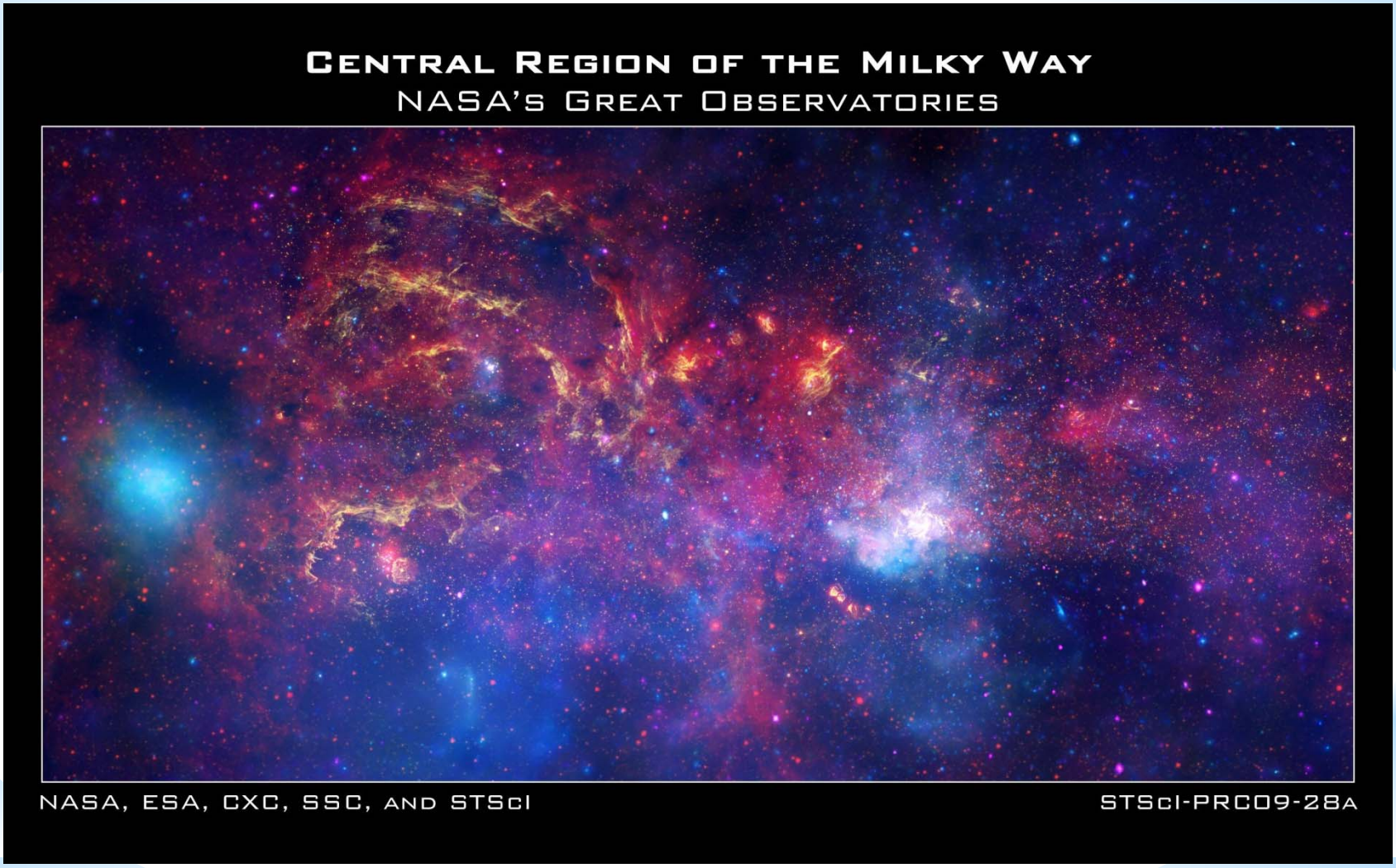


Cluster of Galaxies



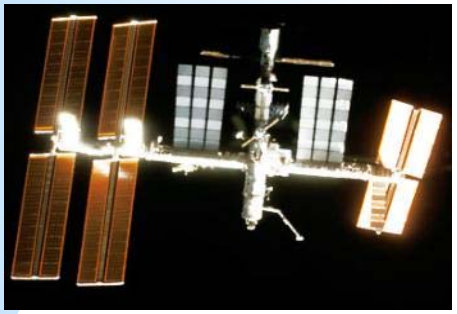
Galaxy Cluster Abell 1689
Hubble Space Telescope • Advanced Camera for Surveys

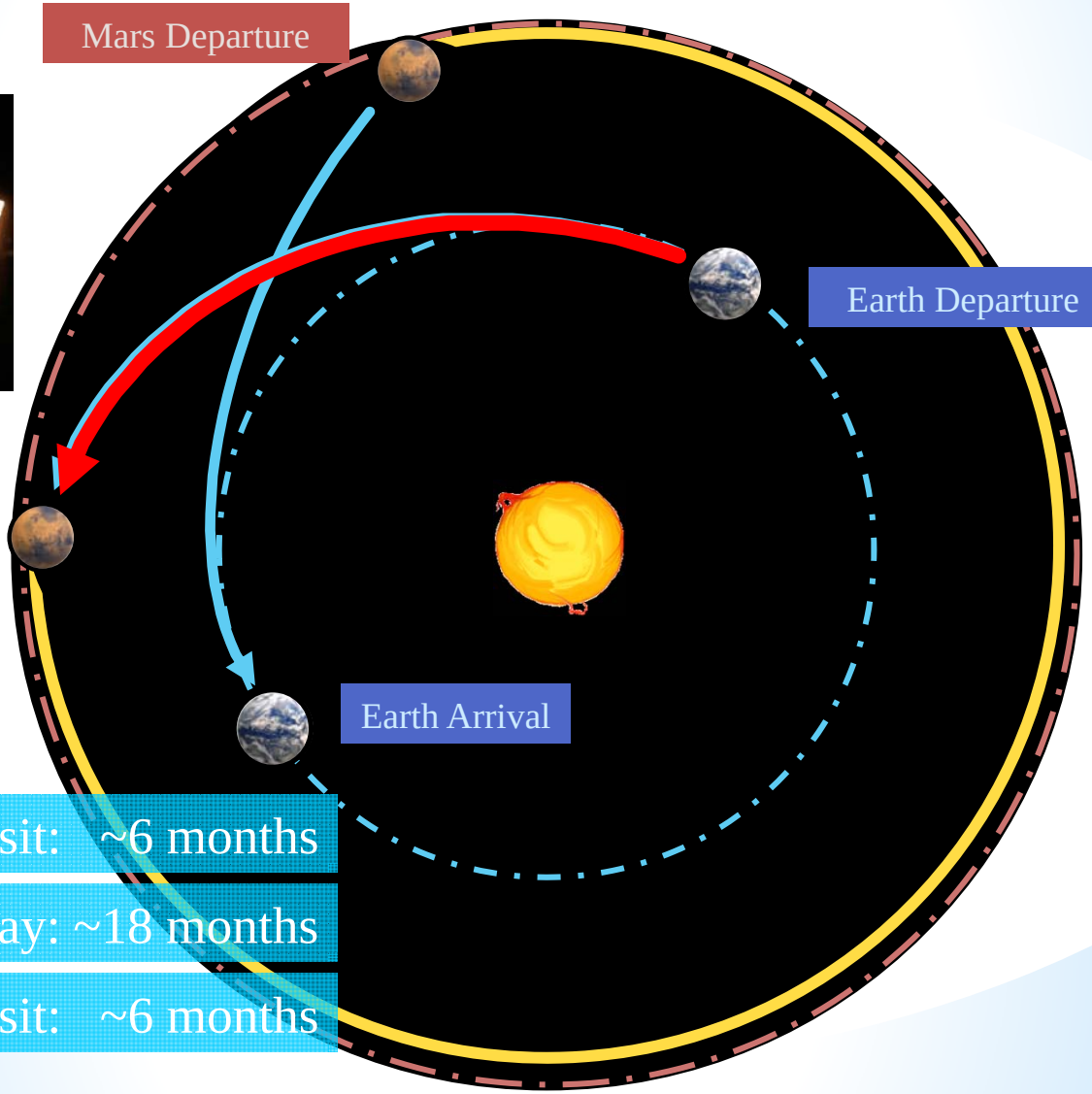
NASA, N. Benitez (JHU), T. Broadhurst (The Hebrew University), H. Ford (JHU), M. Clampin(STScI), G. Hartig (STScI), G. Illingworth (UCO/Lick Observatory), the ACS Science Team and ESA
STScI-PRC03-01a


Central Region of the Milky Way
NASA's Great Observatories
NASA, ESA, CXC, SSC, and STScI
STScI-PRC09-28a

Near-term Human Exploration Domains

Overview of Notional Mars Expedition



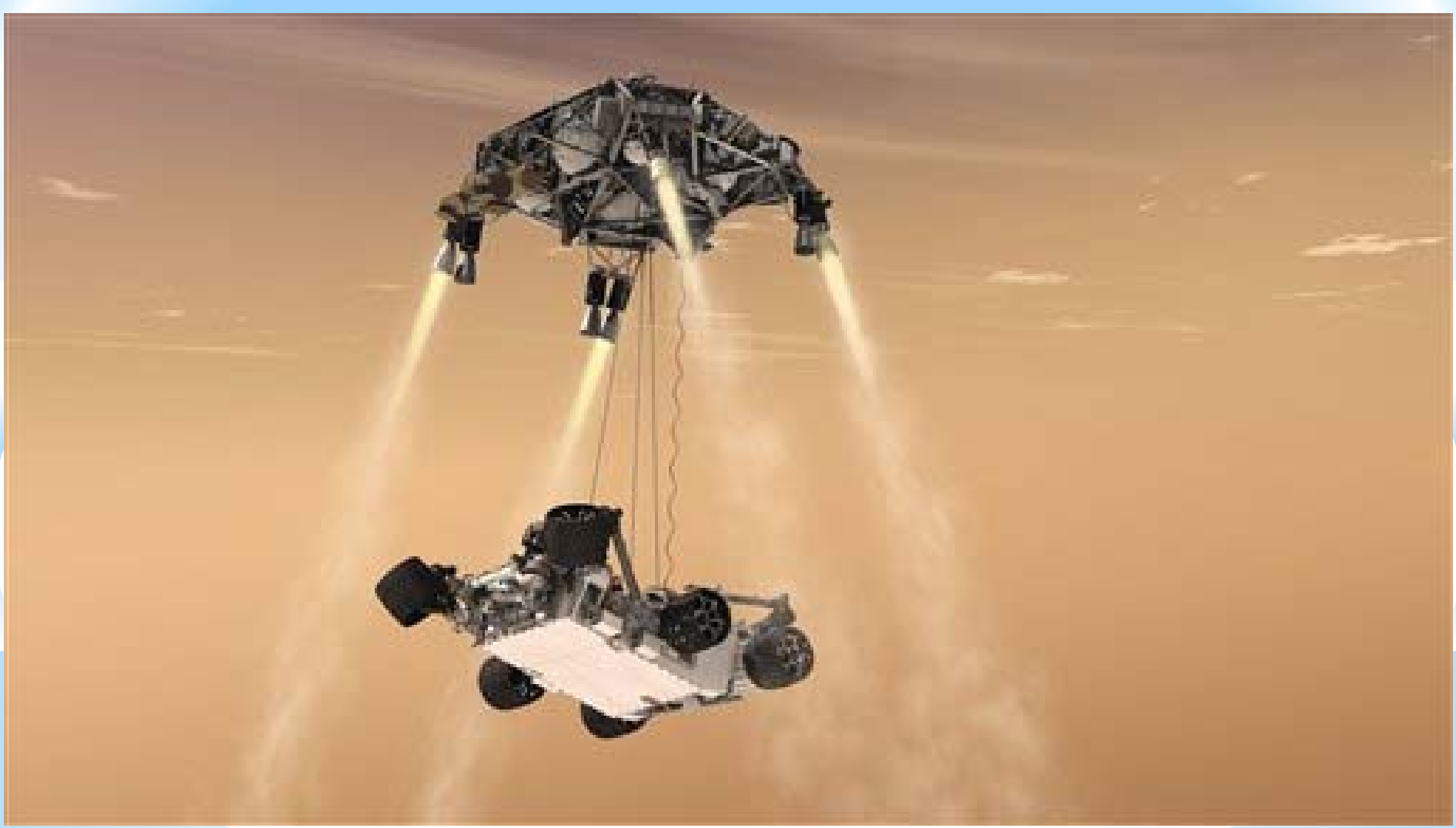


Earth-to-Mars transit: ~6 months

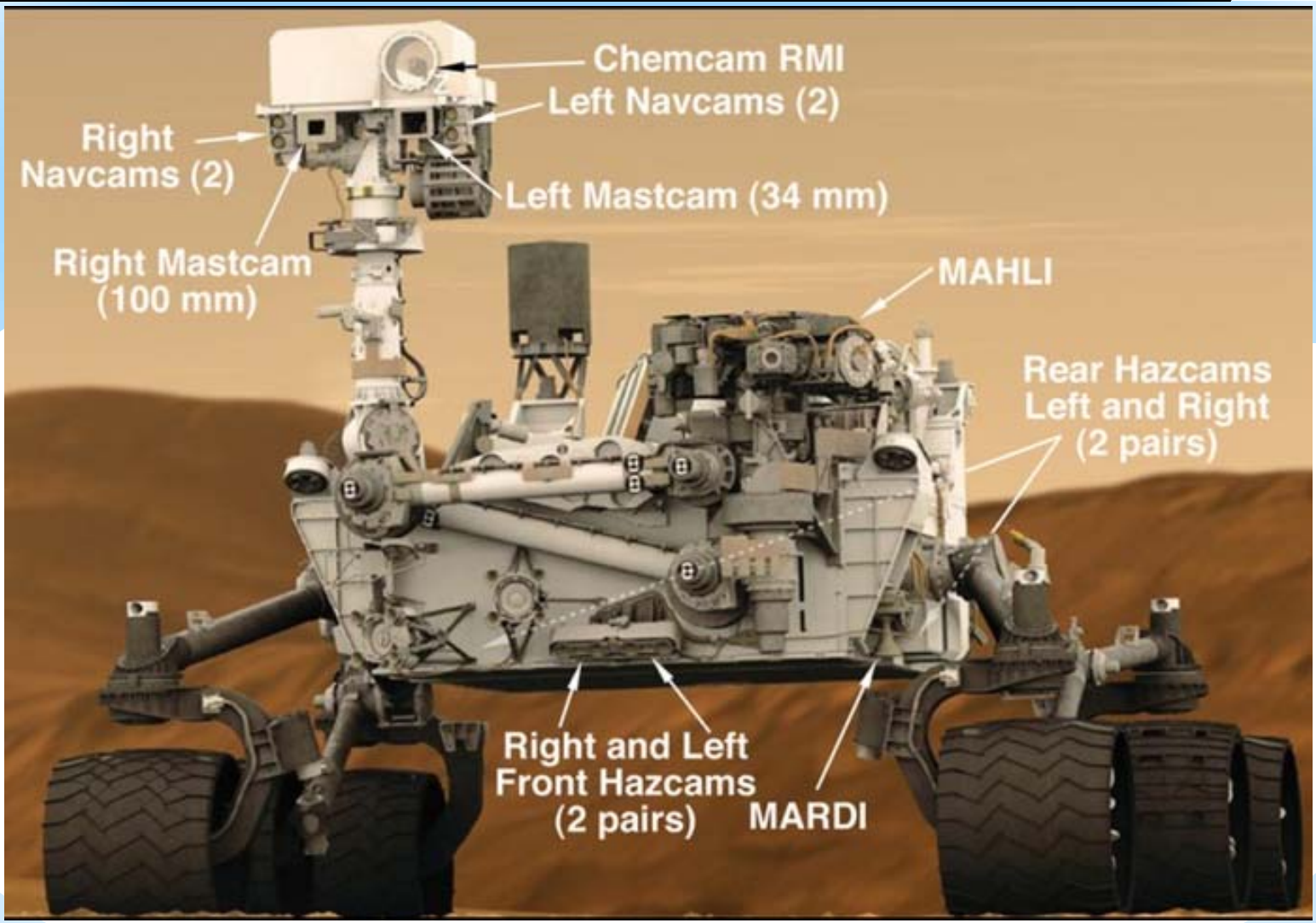
Mars surface stay: ~18 months

Mars-to-Earth transit: ~6 months

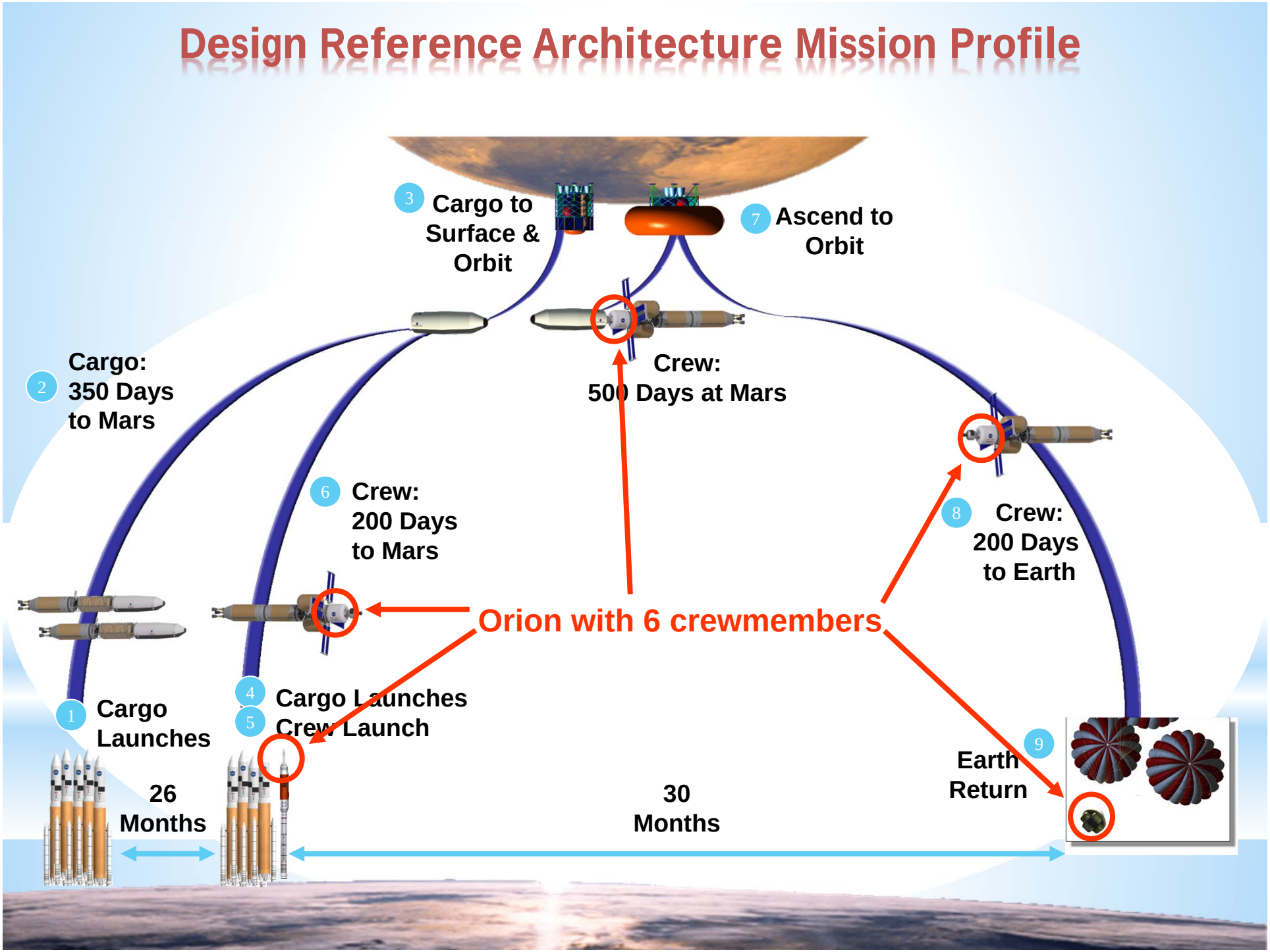
Mars Landing



Mars Rover Cameras

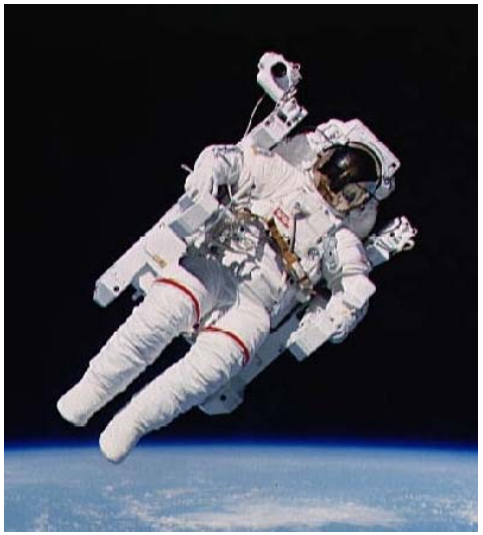


Design Reference Architecture Mission Profile



Life Support Requirements Mass Breakdown

5.02 - 30.74 kg per person-day



11.3 Metric Tons Per Person-Year

DAILY INPUTS - NOMINAL

	kg
Oxygen	0.84
Food Solids	0.62
Water in Food	1.15
Food Prep Water	0.79
Drink	1.62
Hand/Face Wash Water	1.82
Shower Water	5.45
Clothes Wash Water	12.50
Dish Wash Water	5.45
Flush Water	0.50
TOTAL	30.74

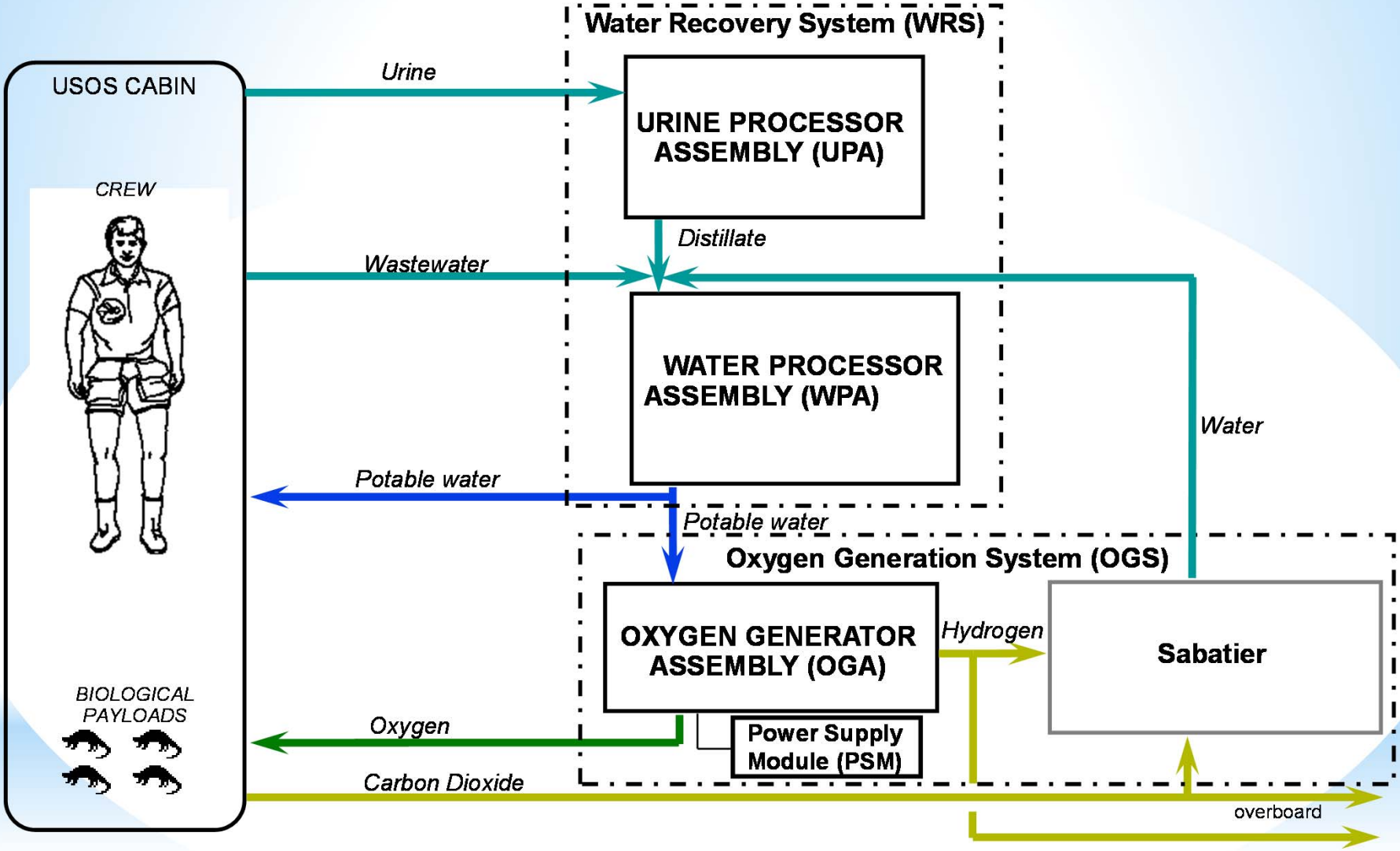
Resources and Recycling

- Water Regeneration Reactors
- Air Revitalization Reactors
- Environmental Sensors (Chemical)
- Microbial Monitors

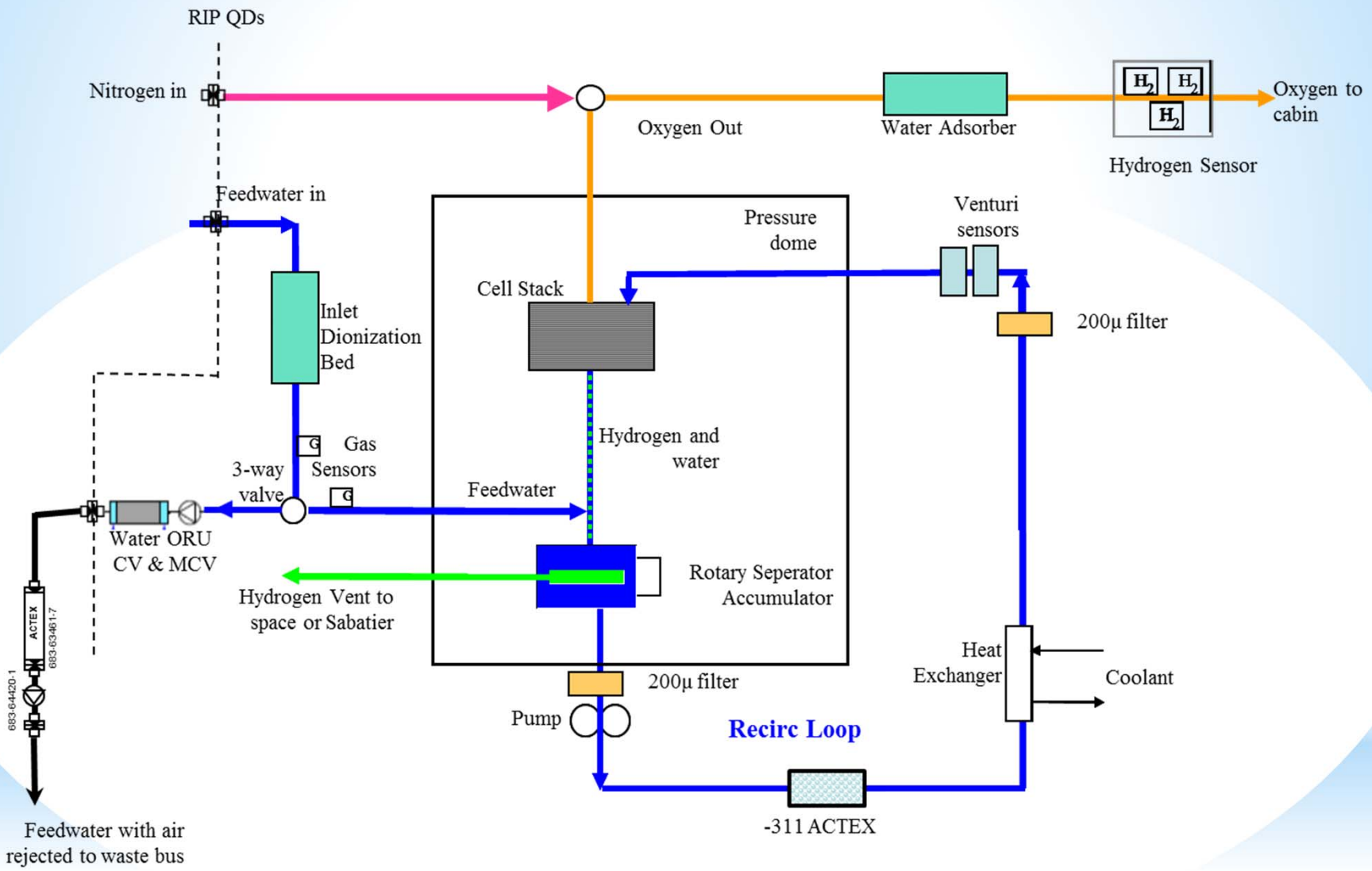
DAILY OUTPUTS - NOMINAL

	kg
Carbon Dioxide	1.00
Respiration and Perspiration Water	2.28
Urine	1.50
Feces Water	0.09
Sweat Solids	0.02
Urine Solids	0.06
Feces Solids	0.03
Hygiene Water	6.68
Clothes Wash Water	11.90
Clothes Wash Latent Water	0.60
Other Latent Water	0.65
Dish Wash Water	5.43
Flush Water	0.50
TOTAL	30.74

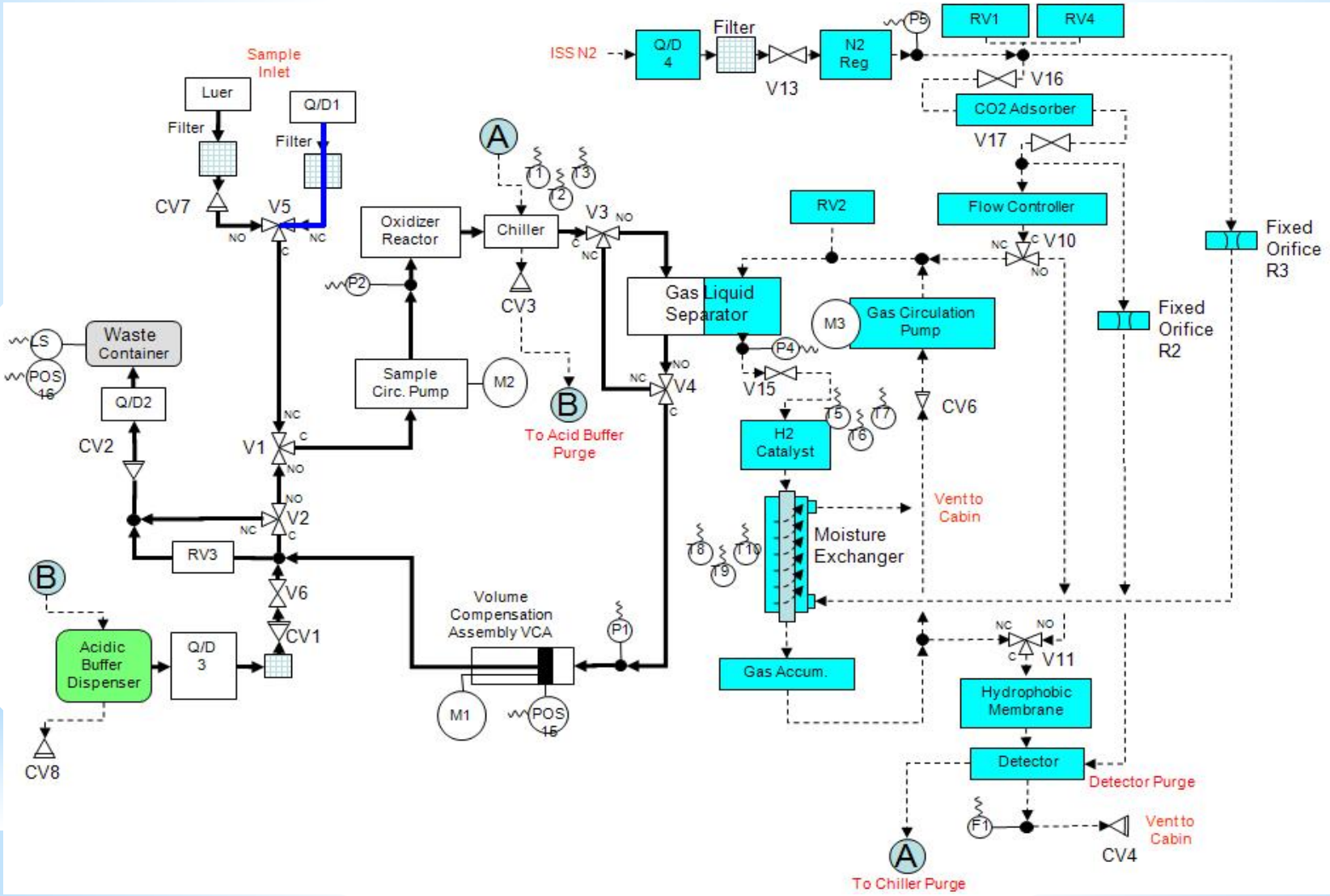
Water and CO2 Recycling



Oxygen Generation System

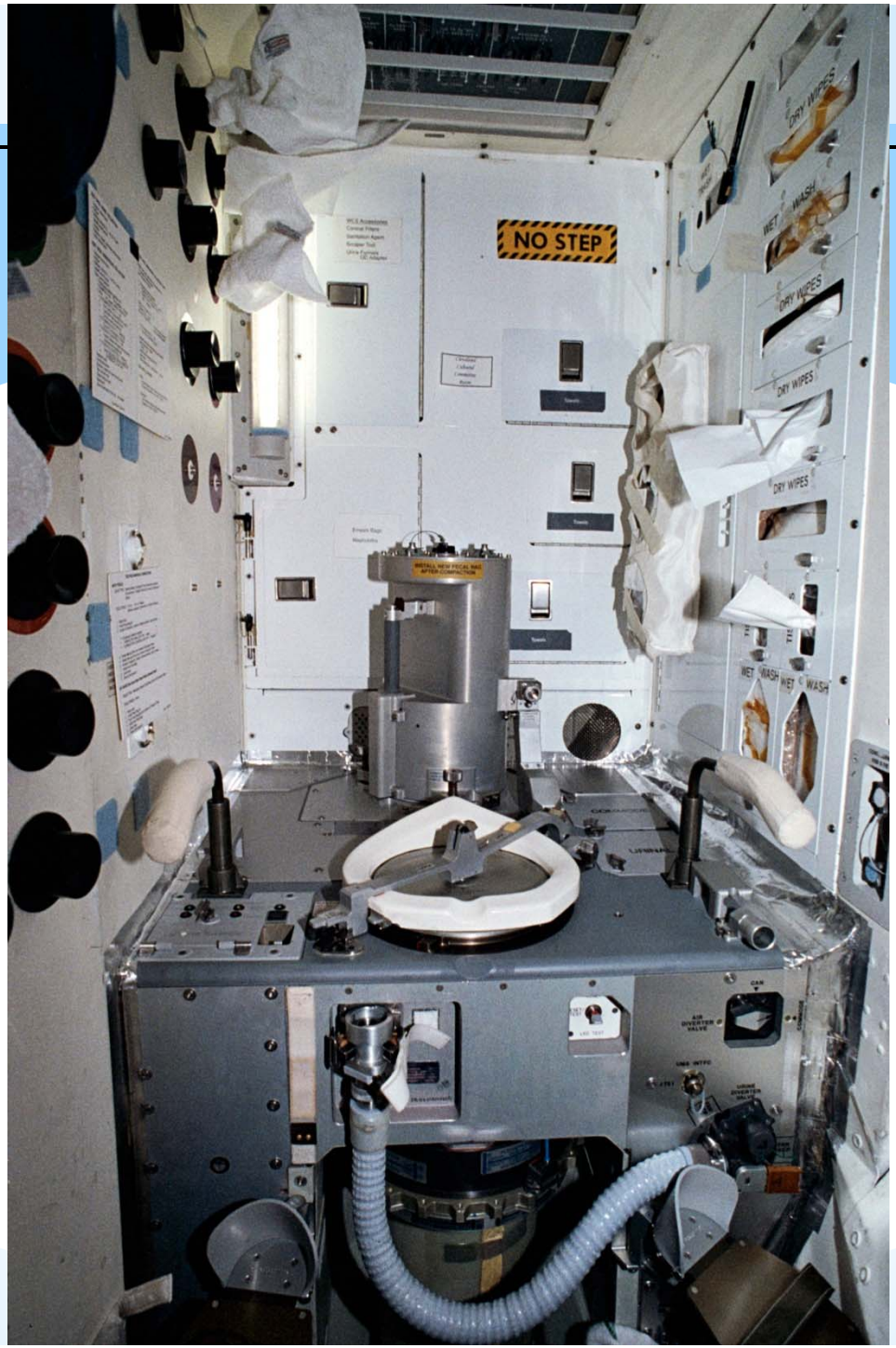


Total Organic Carbon Analyzer



Hygiene

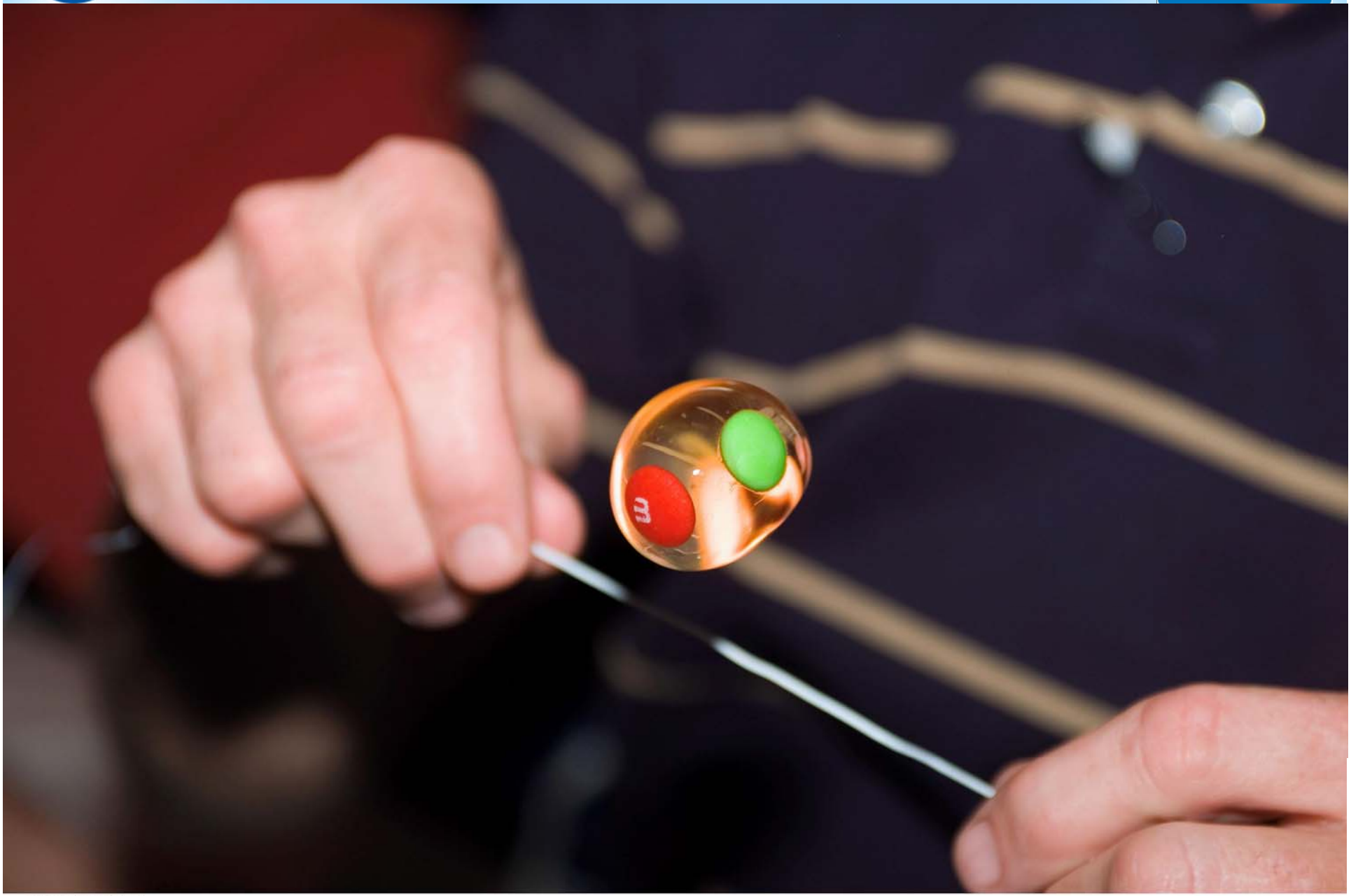
Hair-do


NO STEP
DRY WIPES
WET WASH
DRY WIPES
DRY WIPES
DRY WIPES
WET WASH WET WASH

Garbage Handling

Salt and Pepper

Candies in water bubble



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Dinner at his Lap

Yummy Dinner

Food for Space Missions

Refrigerators and freezers not available to maintain food safety and quality

Natural Form Foods

Rehydratable Foods

Intermediate Moisture Foods

Beverages

Irradiated & Thermo-stabilized Foods

Weightlessness

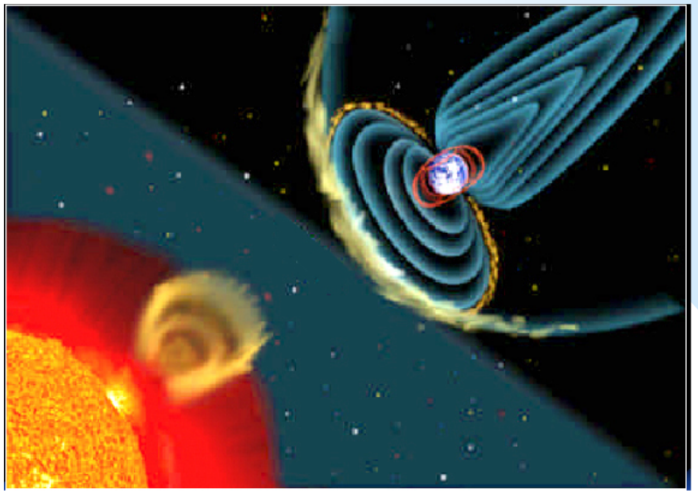
Weightlessness

Super-Woman

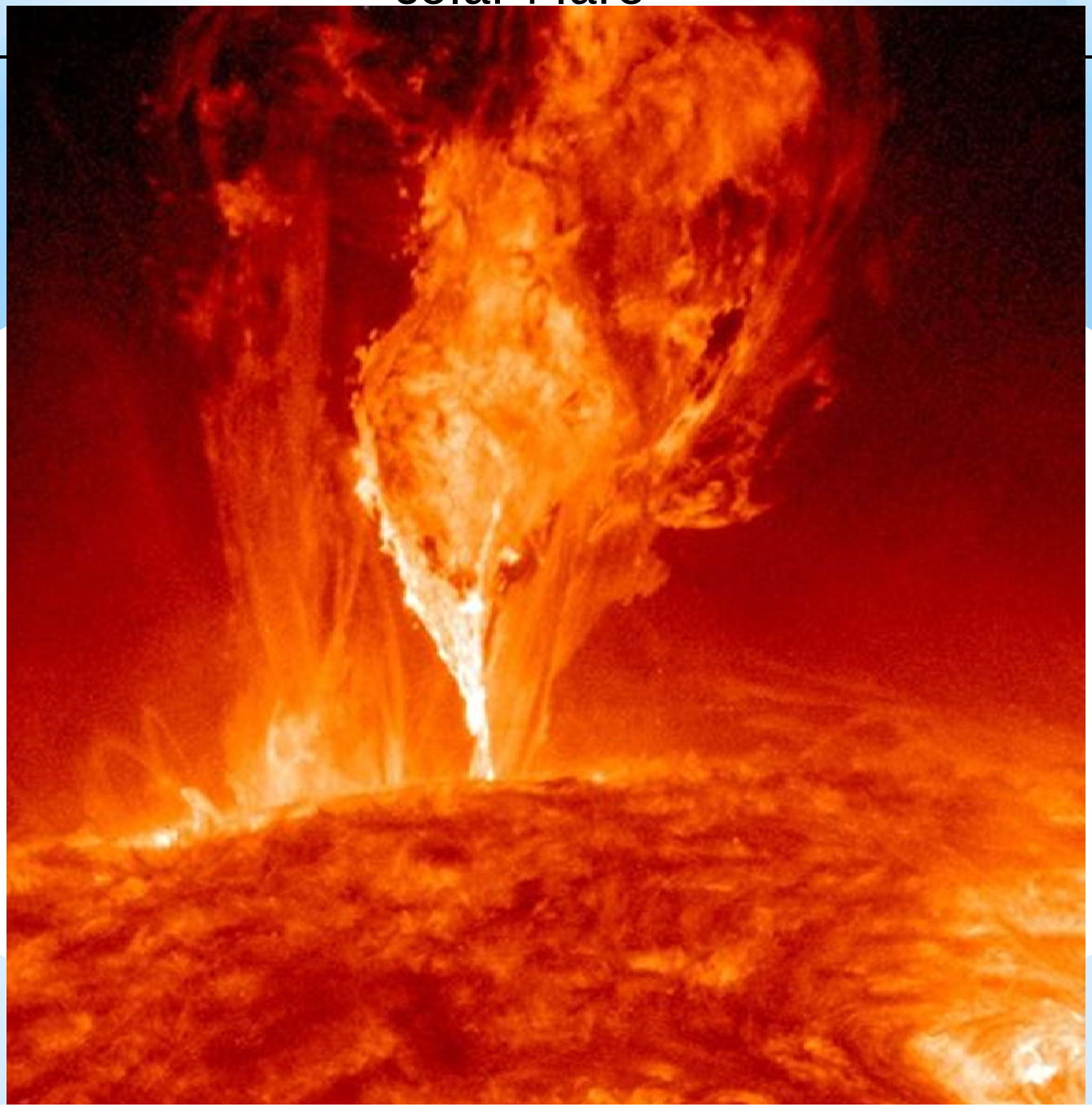
Sleep

Space Radiation Environment

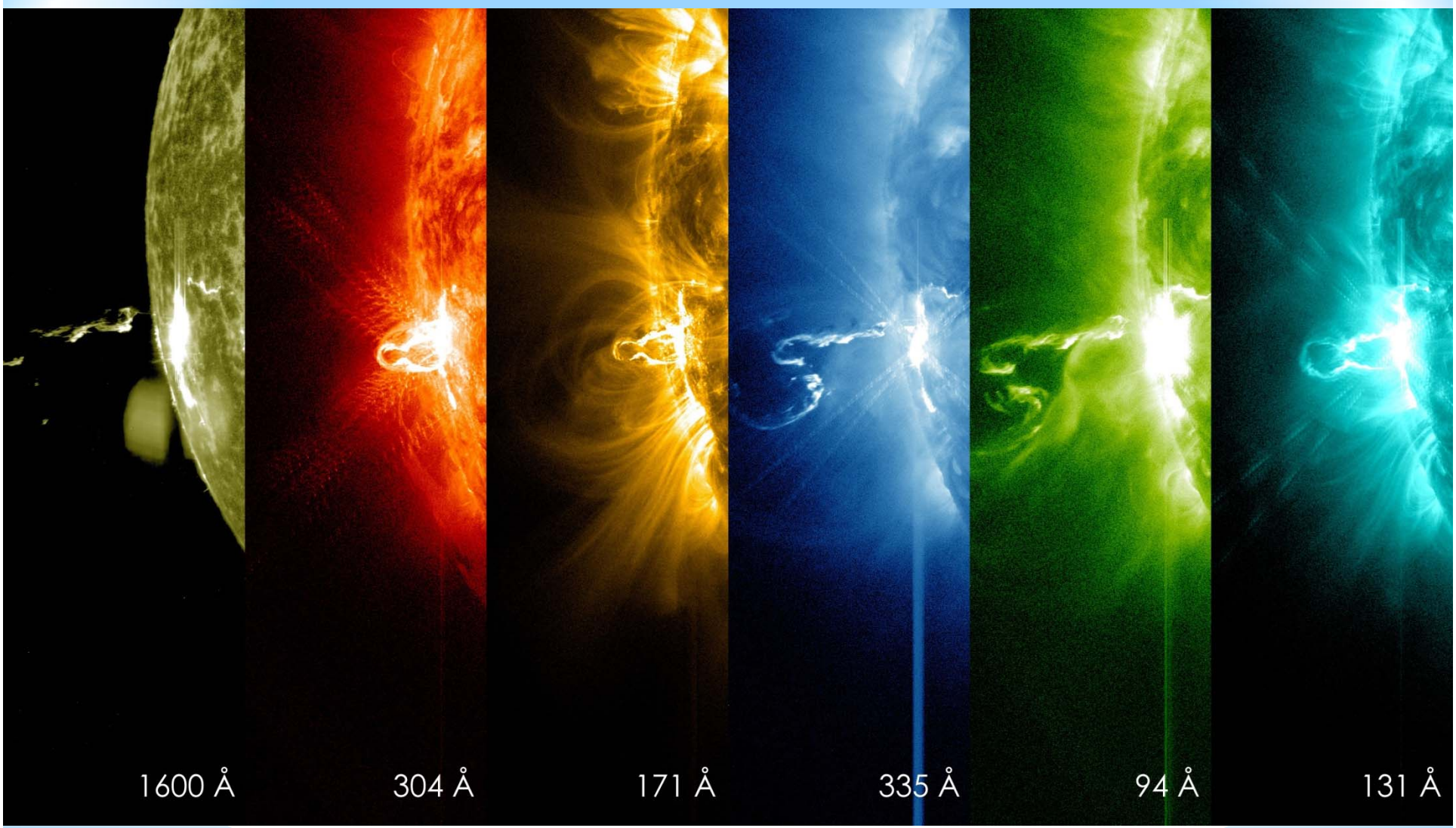
- **Galactic Cosmic Rays (GCR):**
  - highly penetrating protons and heavy ions of extra-solar origin
  - large amounts of secondary radiation
  - largest doses occur during minimum solar activity in 11 year solar cycle
  - low level background radiation: protons (85%), Helium (14%) and HZE particles (1%)
- **Trapped Radiation in South Atlantic:**
  - medium energy protons and electrons
  - effectively mitigated by shielding
- **Solar Particle Events (SPE):**
  - medium to high energy protons
  - occur during maximum solar activity
  - Solar protons from the Coronal Mass Ejections and HZE



Solar Flare

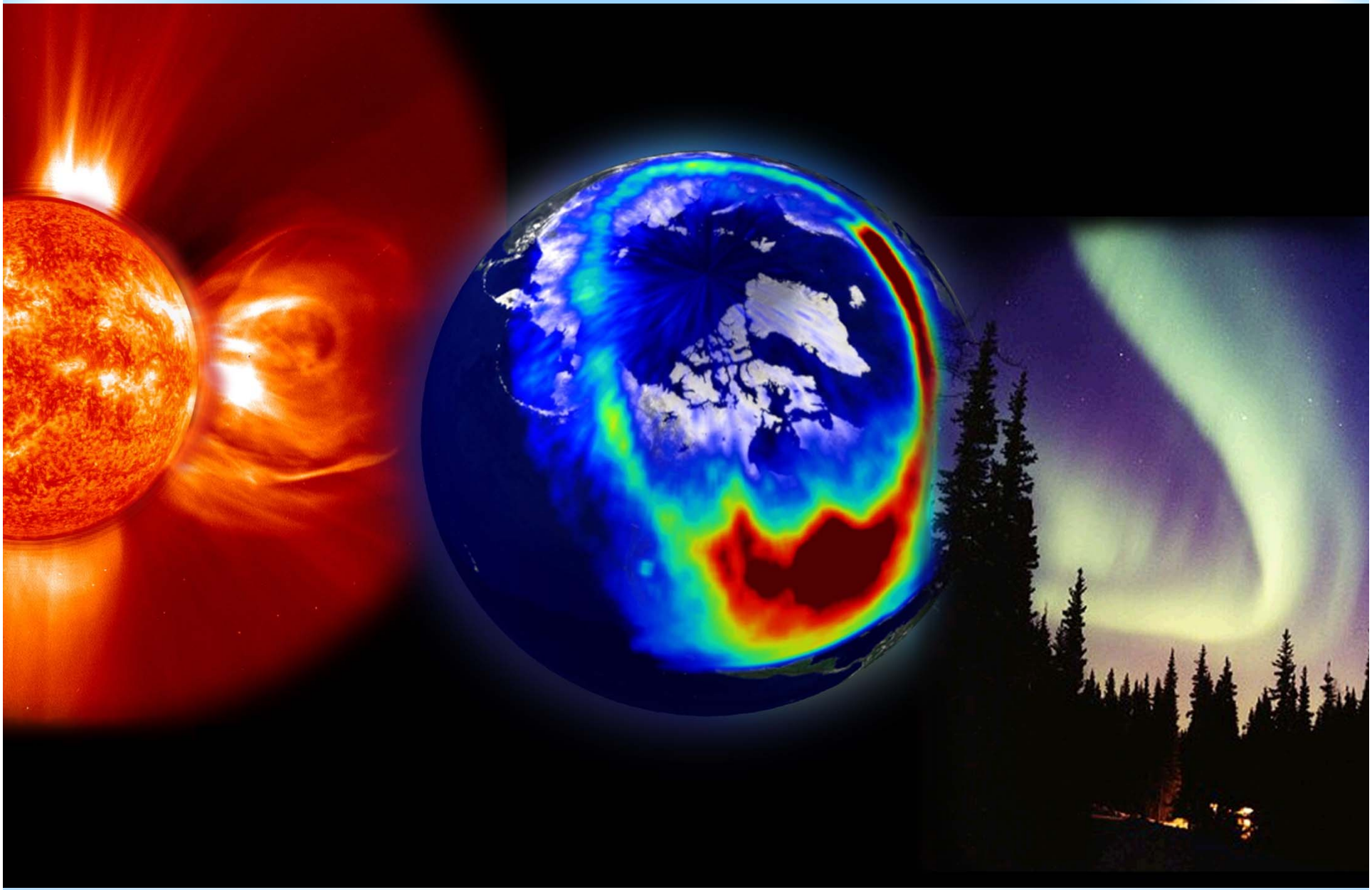


Solar Flare Observed at Various Wavelengths

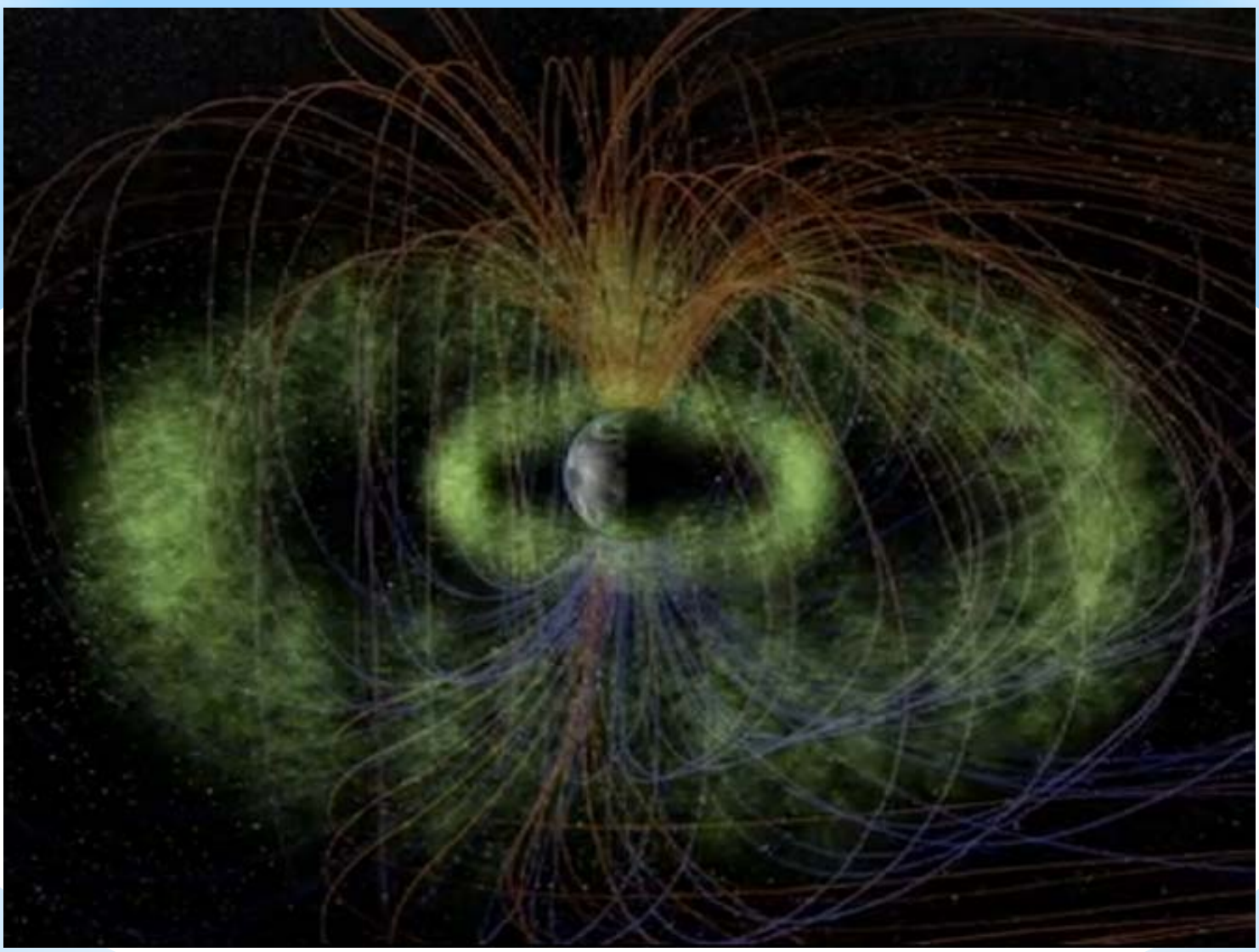


A. Jeevarajan/NASA

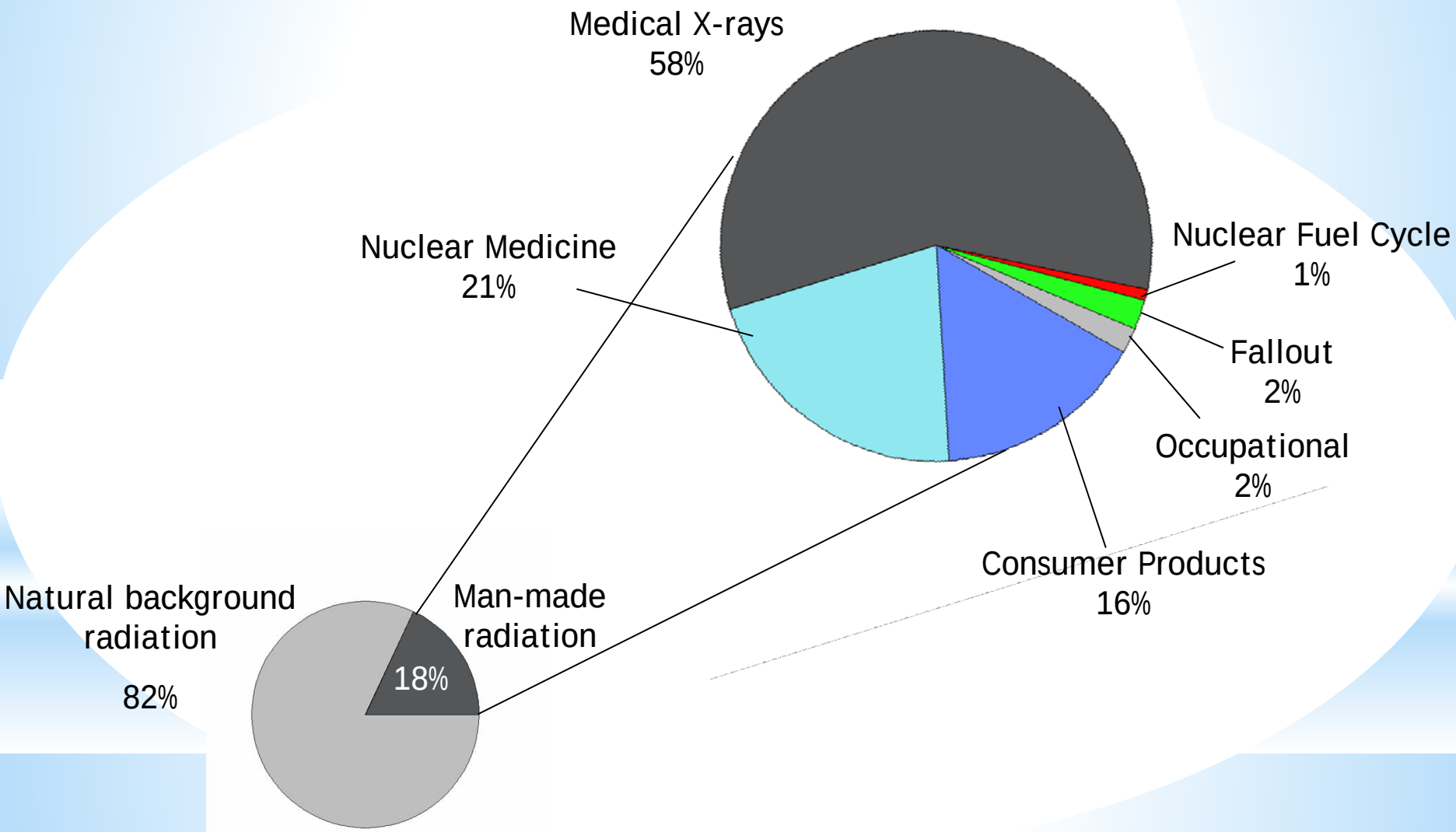
Solar Flare/Aurora from Space/Earth



Van Allen Belt

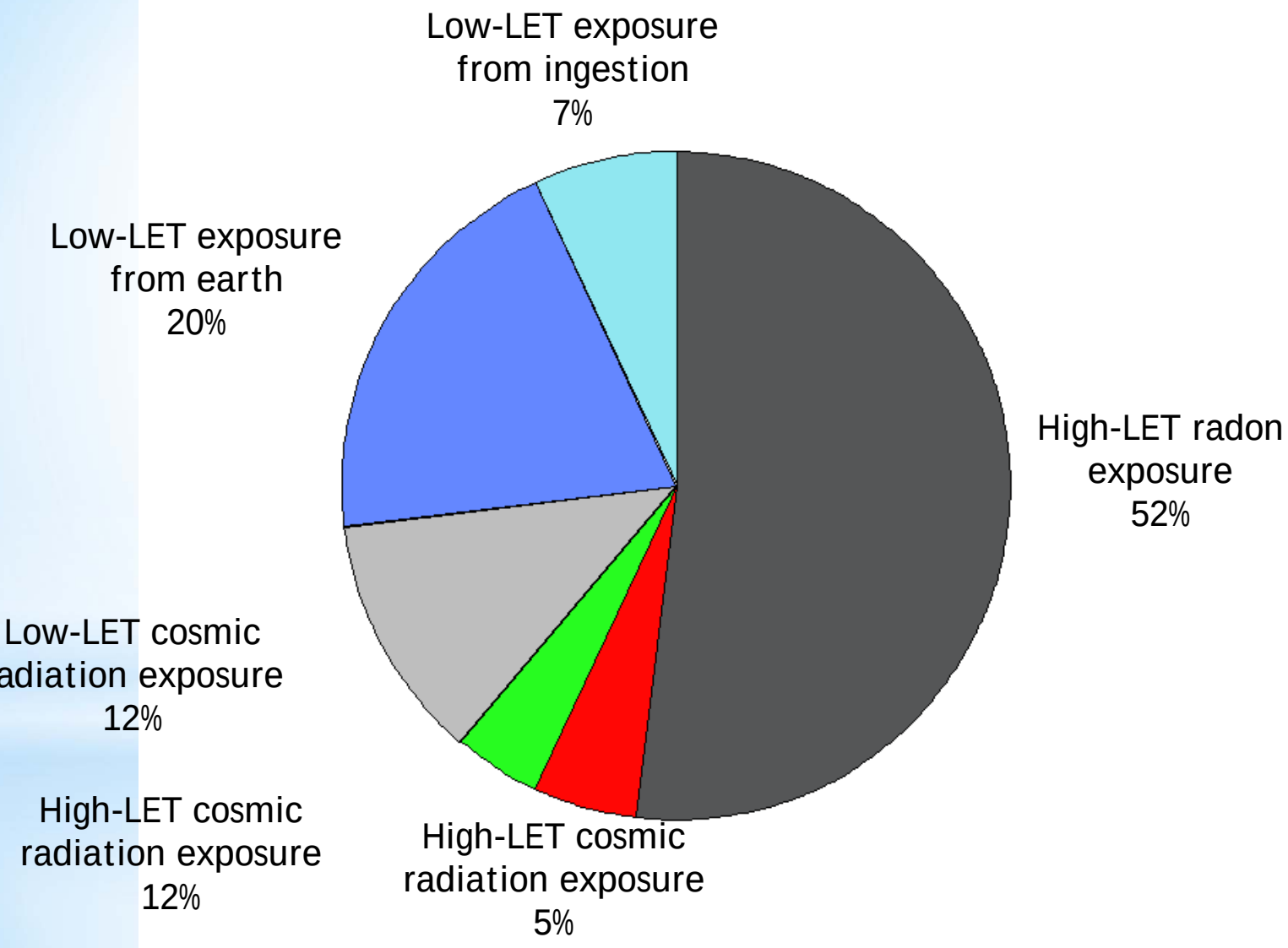


Contribution to exposure from man-made Radiation sources in USA



Data: BEIR VII 2006, NCRP 1987

Environmental exposure to natural background radiations: 2.4 mSv/year



Approximate Response of a single Mammalian Cell to 1Gy of Radiation

Radiation	***Low-LET***	***High-LET***
Tracks in nucleus	10^3	4
total SSB	10^3	10^3
total DSB	~ 40	< 40
Complex DSB	20%	70%
DSB per lethal lesion	87	22
Chrom. Aberration	1	3
Dicentric per cell	0.1	0.4
Cell Inactivation	30%	85%

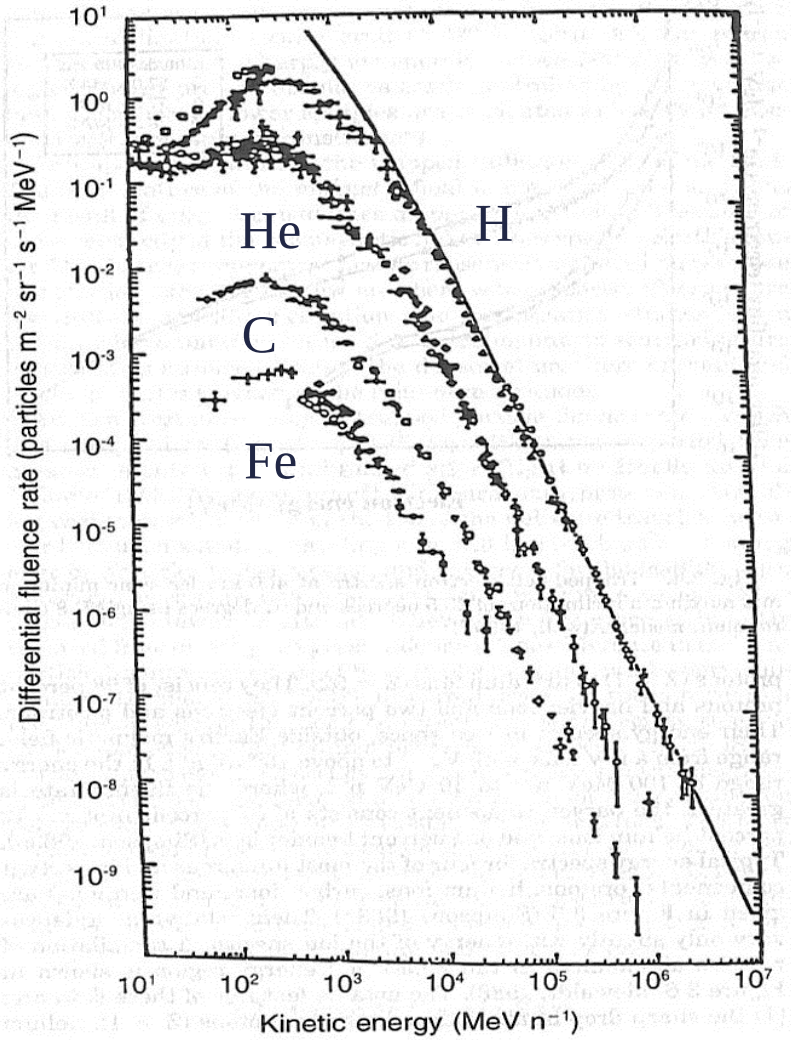
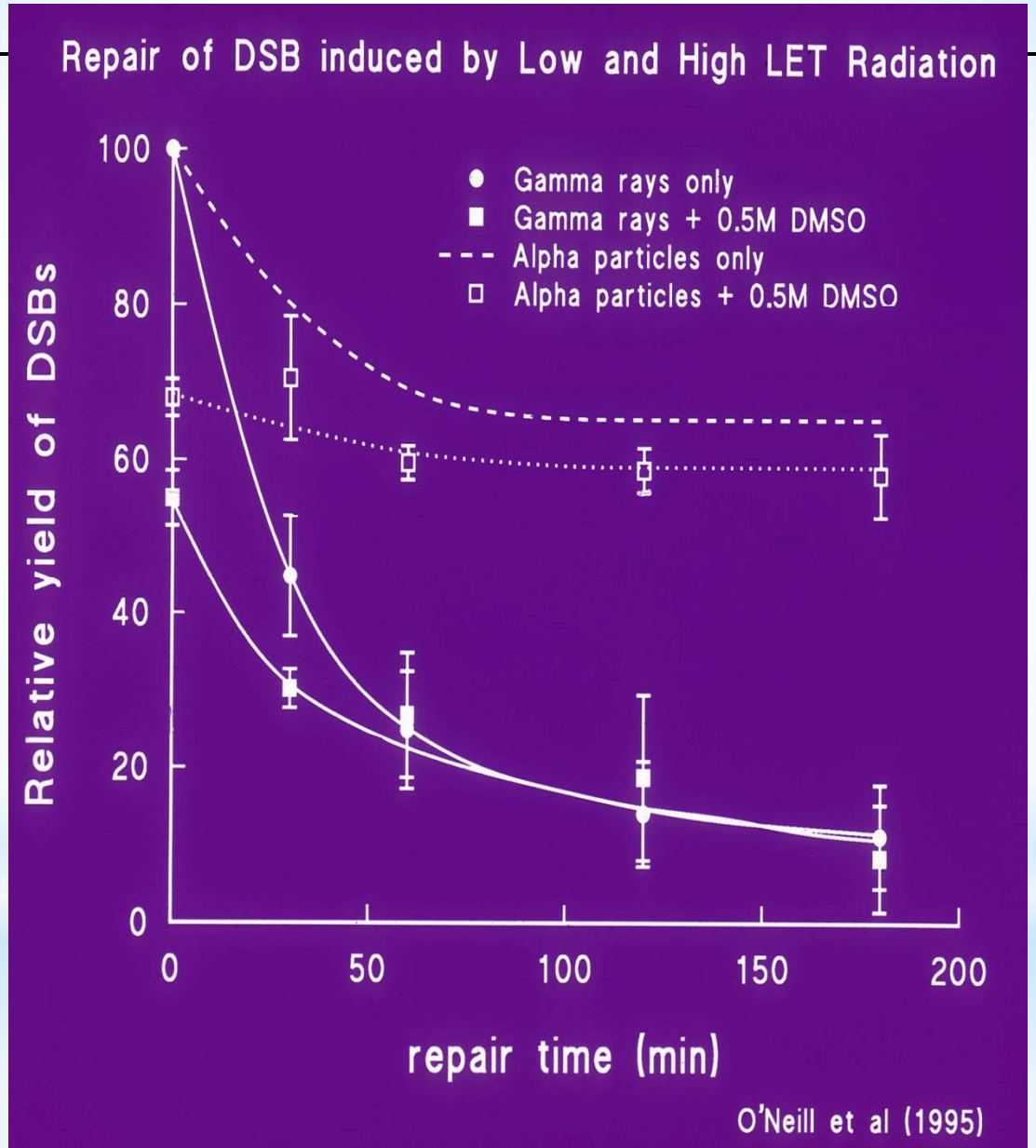


Fig. 3.5. Typical energy spectra for protons, helium ions, carbon ions, and iron ions from "top to bottom," respectively, at solar minimum. The solid line is the local interstellar spectrum (Simpson, 1983a).

Energy Spectra for protons, helium, carbon, and iron.


Repair of DSB induced by Low and High LET Radiation
Gamma rays only
Gamma rays + 0.5M DMSO
Alpha particles only
Alpha particles + 0.5M DMSO
Relative yield of DSBs
100
80
60
40
20
0
0
50
100
150
200
repair time (min)
O'Neill et al (1995)

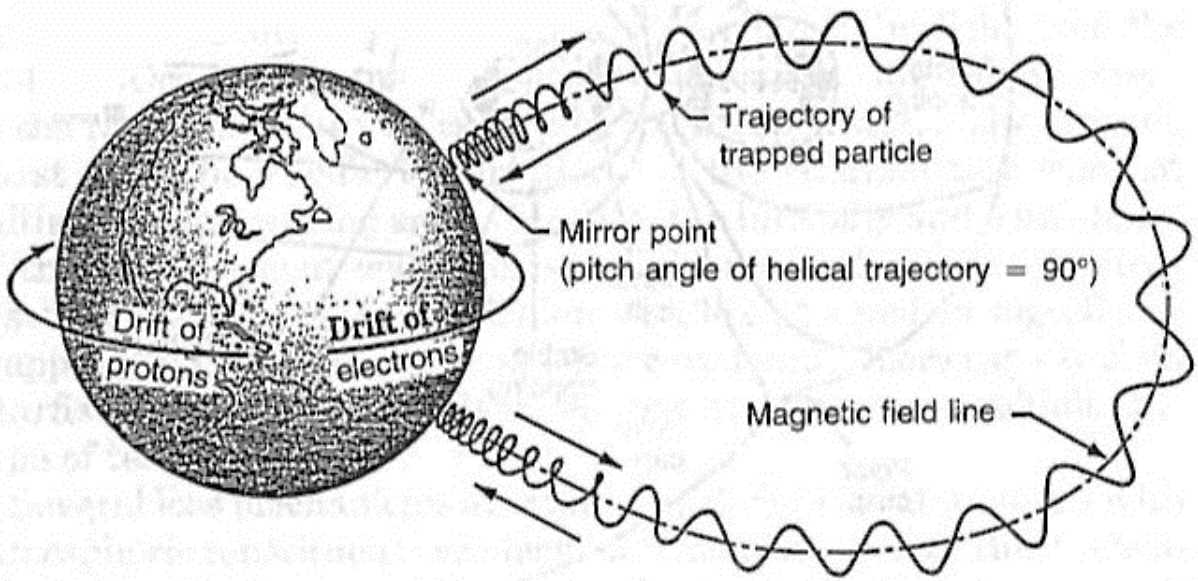


Fig. 3.2. The motion of a charged particle in a dipole magnetic field consists of three components; a helical trajectory about the magnetic field line, a bounce between polar mirror points, and a longitudinal drift around Earth (Hess, 1968).

Charged Particle Motions in Earth's Magnetic Field

van Allen Belt Particles

Components:

Protons: ~ 0.04 to 500 MeV

Electrons: ~ 0.04 to 7 MeV

Heavier Ions: Low Energies

Location of peak levels is energy dependent

Location of populations shifts with time

Average counts vary slowly with solar cycle

Counts may increase by orders of magnitude with magnetic storms

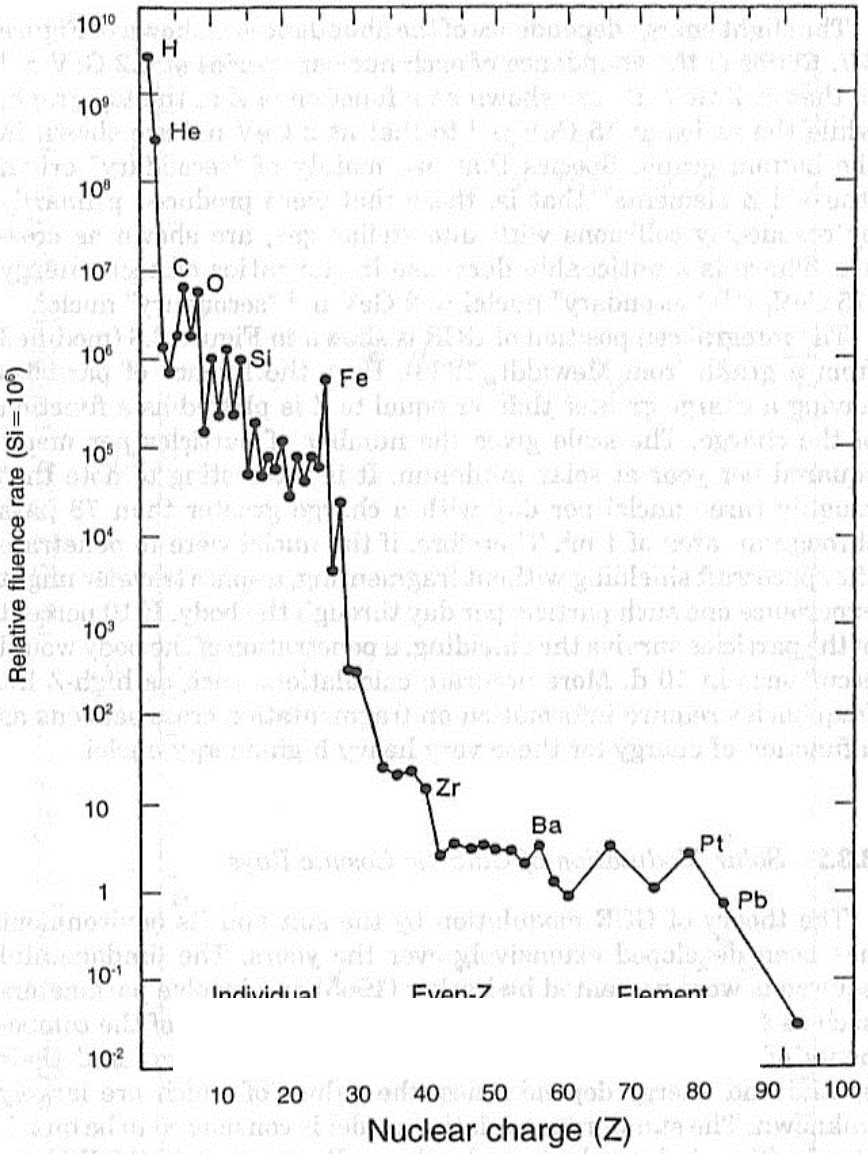
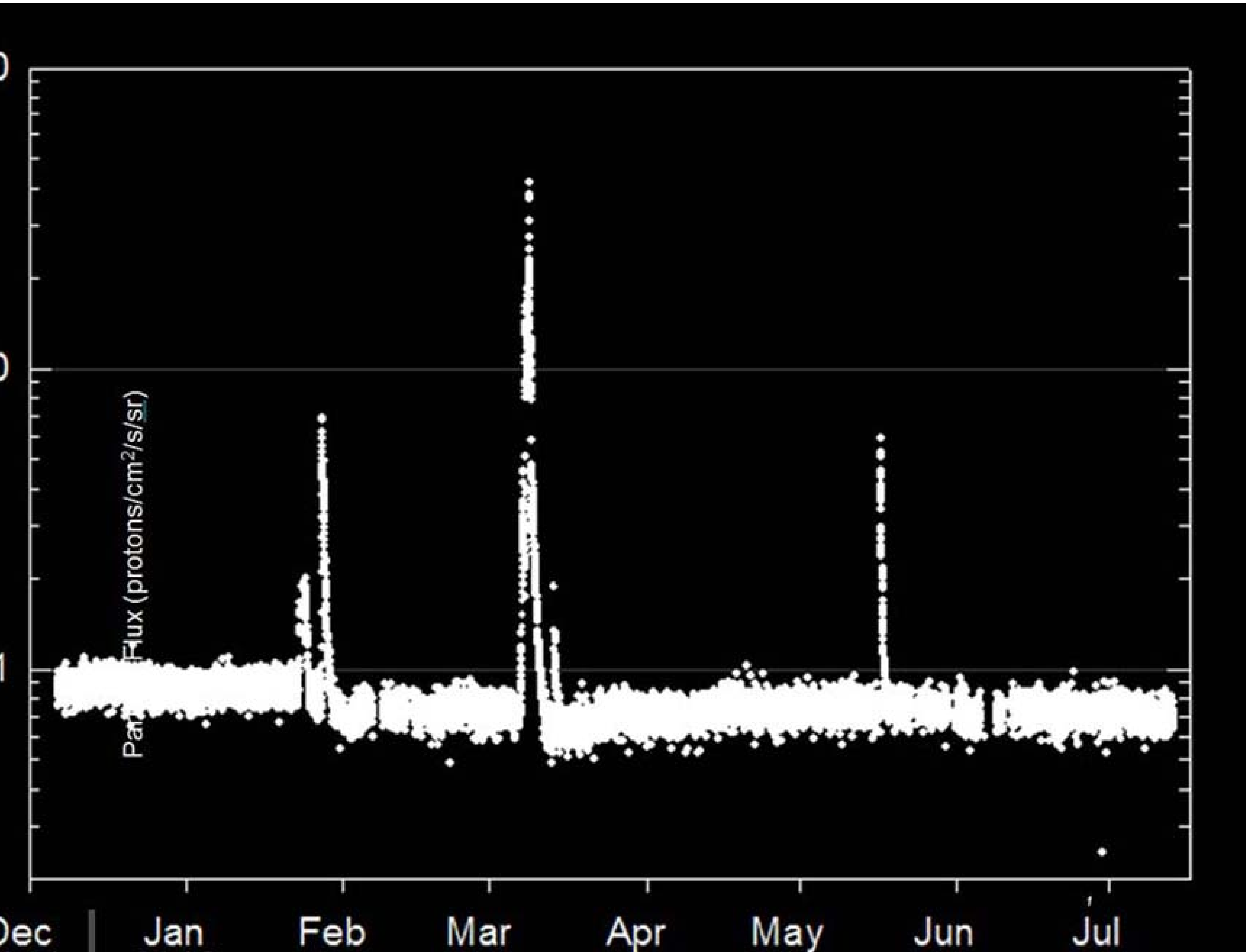


Fig. 3.6. Nuclear composition of GCR (~2 GeV n^{-1}) (Mewaldt, 1988).

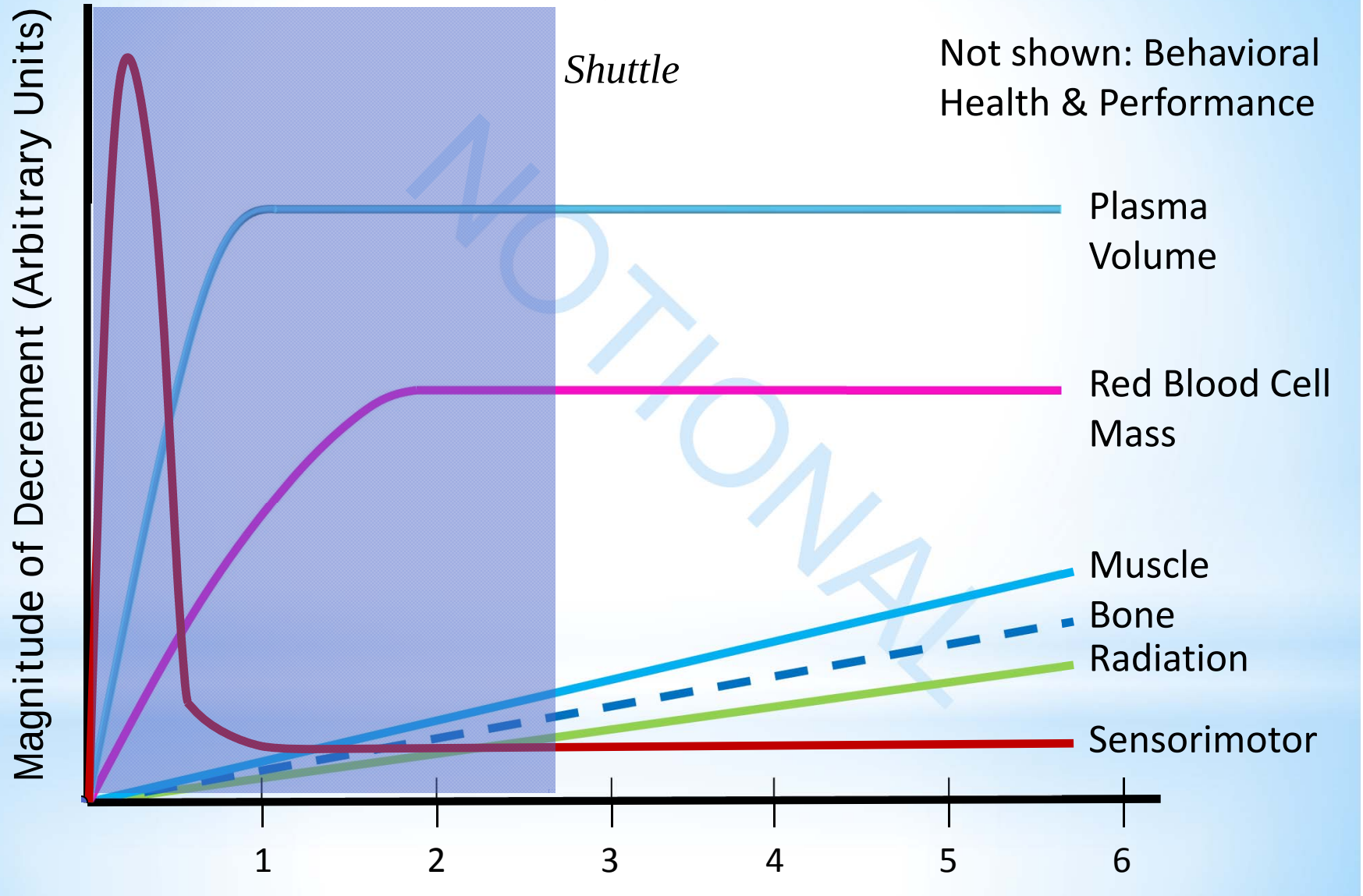
Galactic Cosmic Radiation

Nuclear composition of galactic cosmic rays.

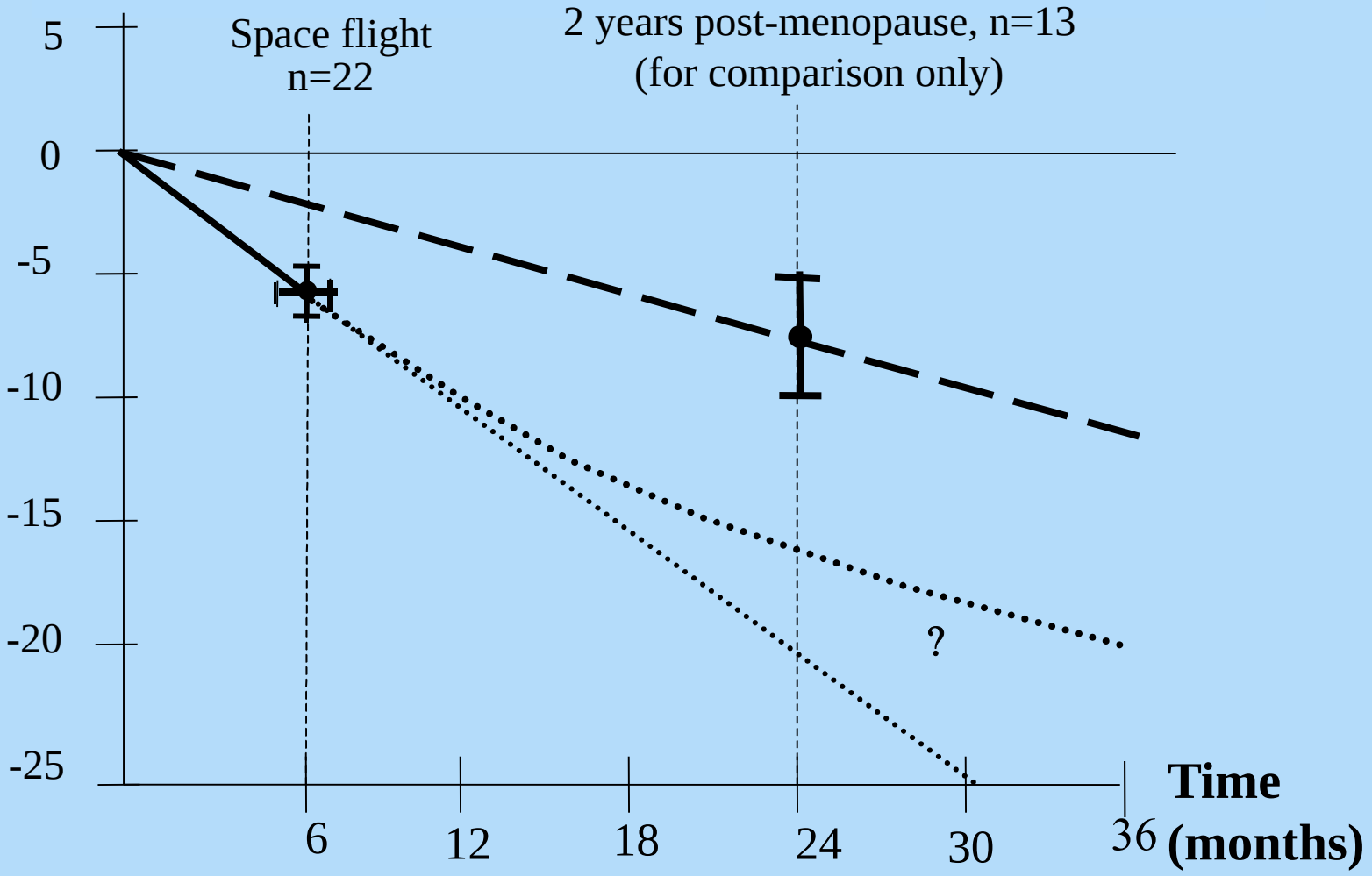
Log fluence rate vs. atomic number.

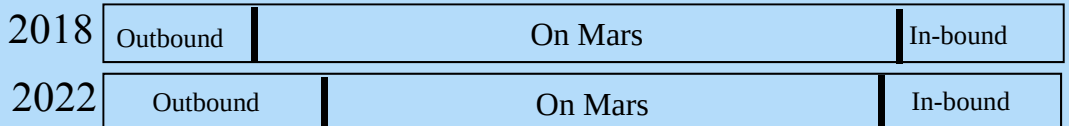

Particle Flux (protons/cm^2/s/sr)
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul

Changes during short-duration space flight



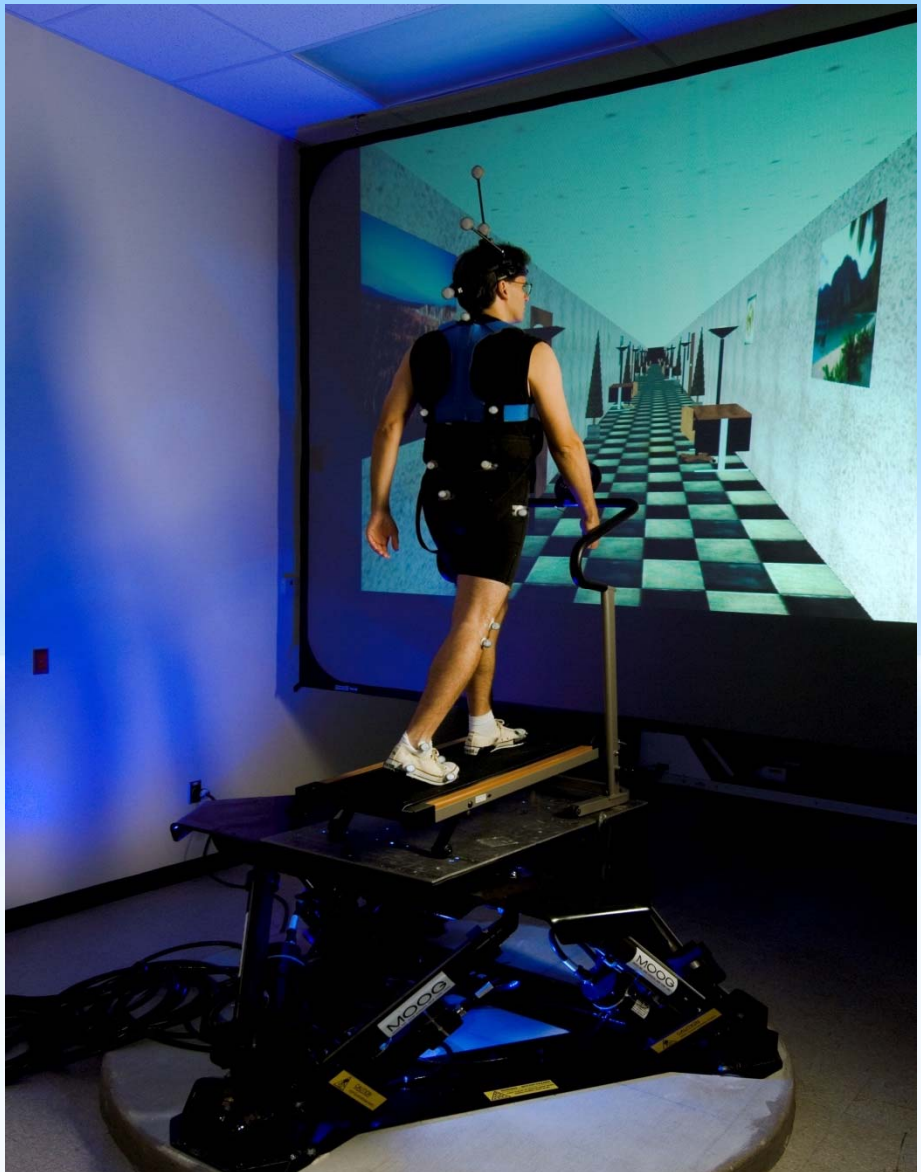
Bone Loss During Space Missions



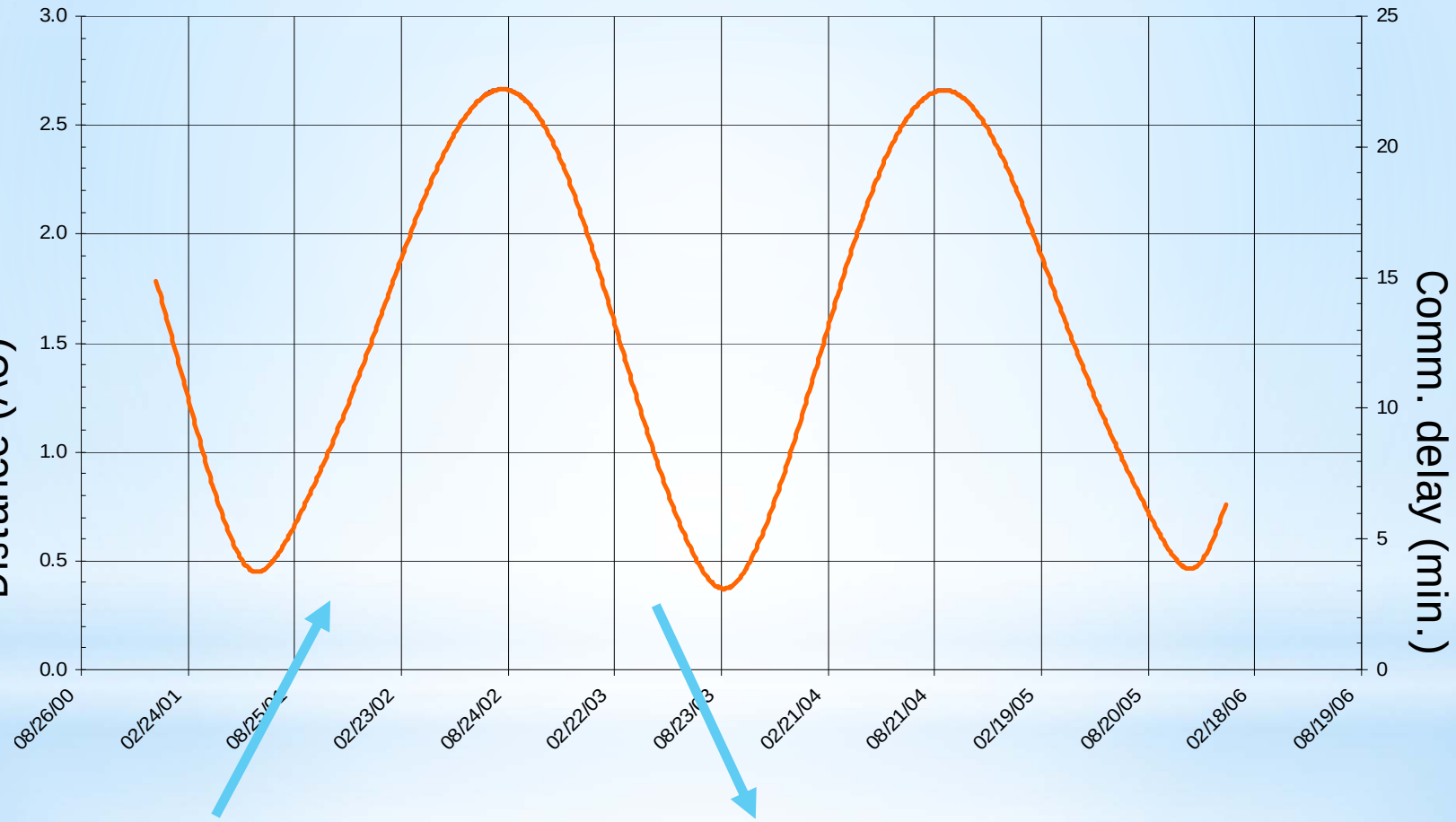


Mission Opportunities

Treadmill in a six-degree of freedom Platform



Variation in Distance and Communications Delay Between Earth and Mars

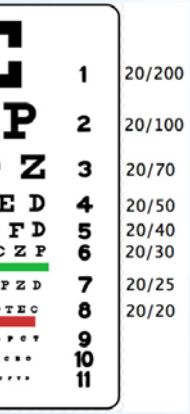


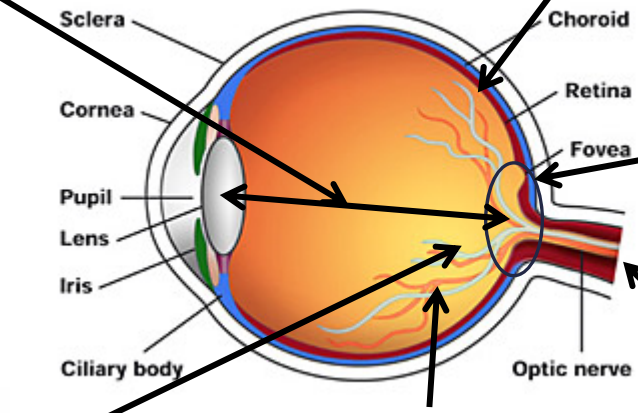
Integrated Visual Impairment/Intracranial Pressure

Human Health and Performance
NASA JOHNSON SPACE CENTER
Exploring Space | Enhancing Life

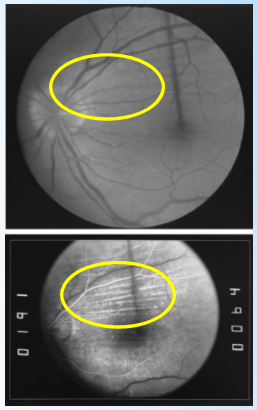
eropic Shifts

o +1.75 diopters

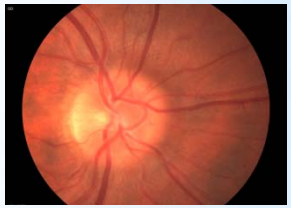




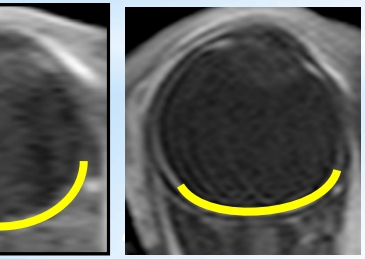
•Choroidal Folds - parallel grooves in the posterior pole



•Optic Disc Edema (swelling)



e Flattening



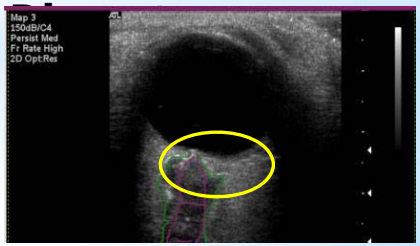
l Globe Flatten Globe

MRI Orbital Image showing globe flattening

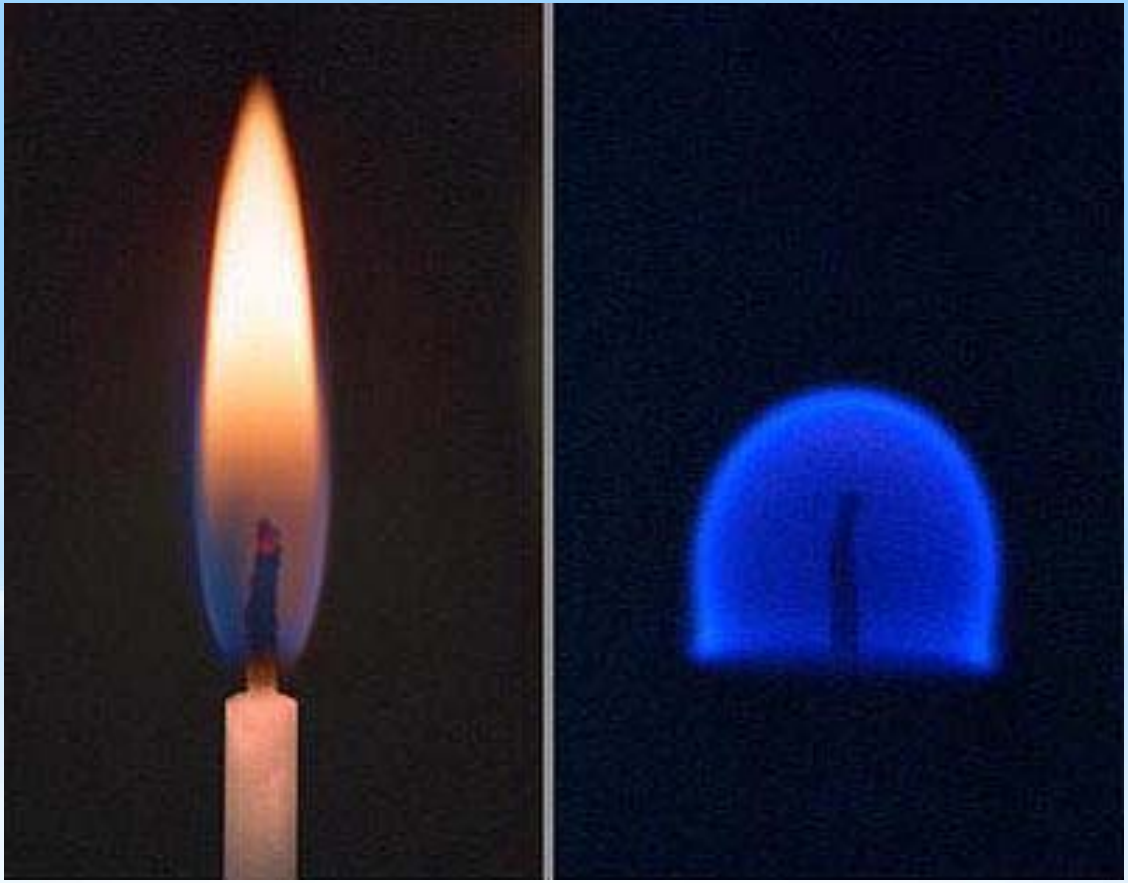
•Altered Blood flow

•"cotton wool" spots

•Increased Optic Nerve Sheath



Flame Behaviour

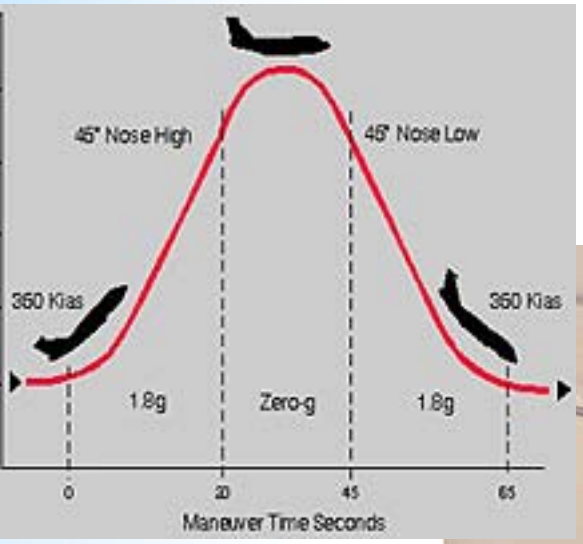



United States
Discovery

Shuttle Launch

International Space Station

The Vomit Comet



Zero-Gravity Aircraft

Space Simulation at Earth - Exercise

Two Shuttles in the Launch Pad

Apollo-1 Fire Accident

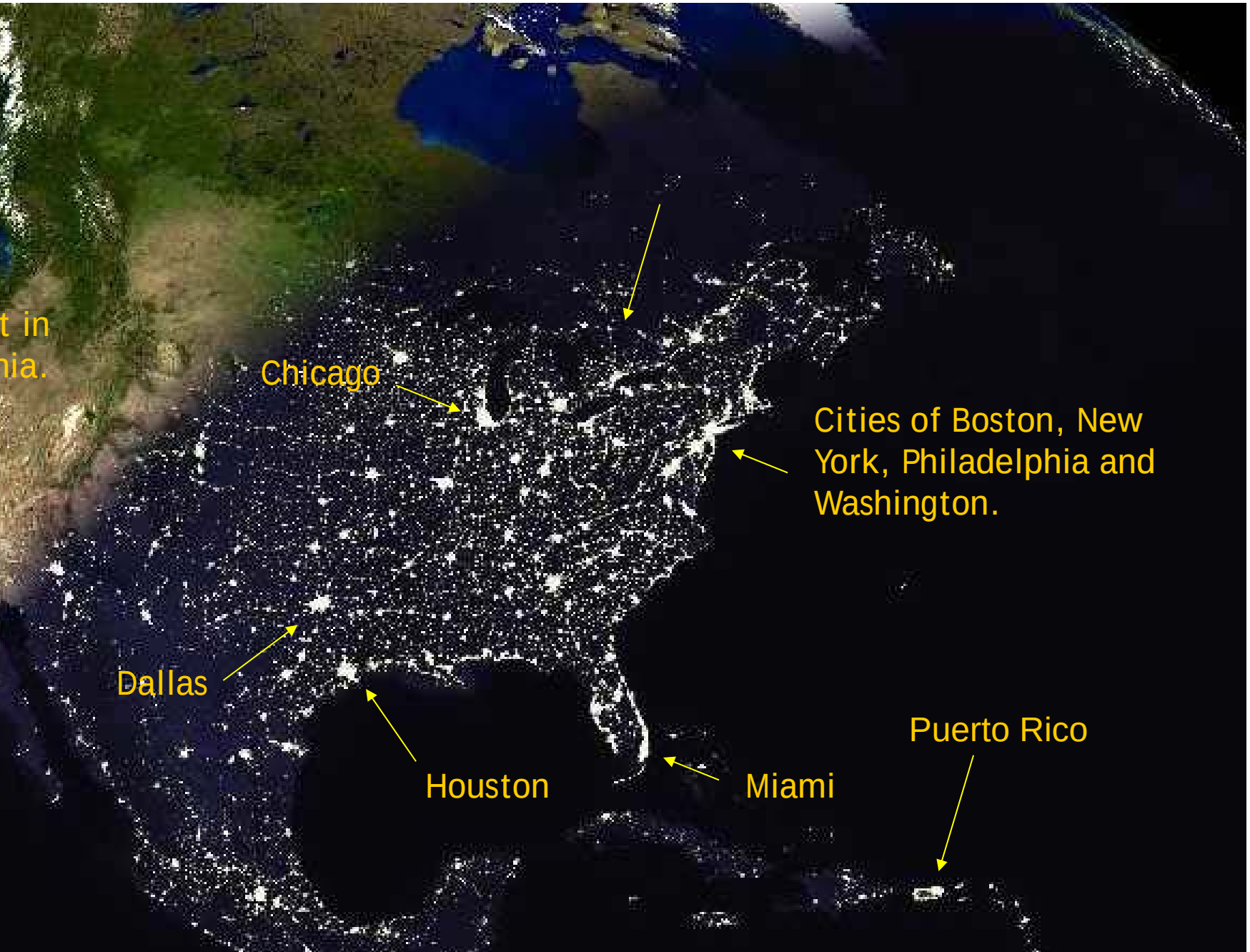
Apollo-1


E.H. WHITE
M.S.C. N.A.S.A
V.I. GRISSOM
M.S.C. N.A.S.A
R. CHAFFEE
NASA
NASA
NASA
UNITED
STATES

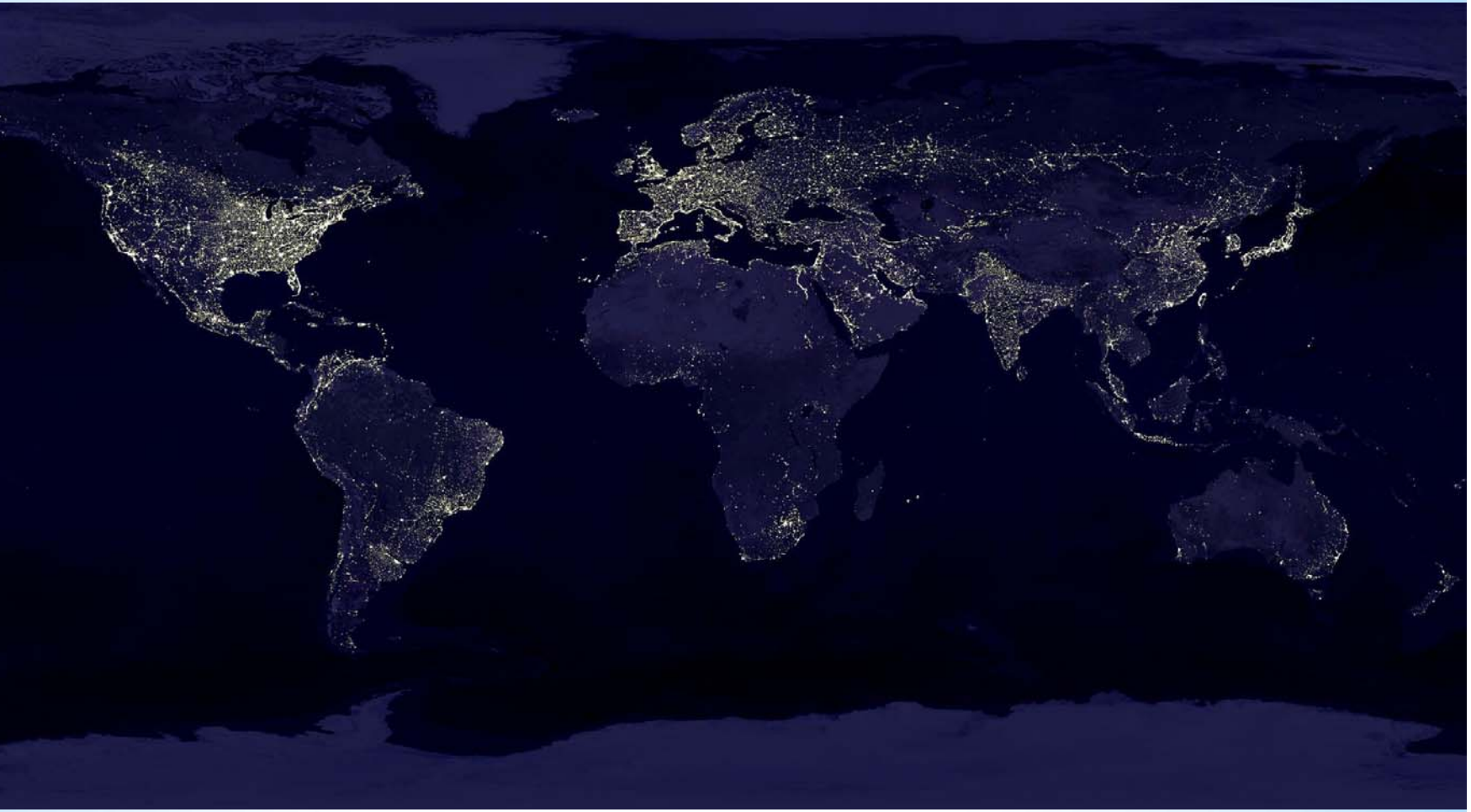

NASA
EL ONIZUKA
MIKE SMITH
DICK
RON McNAIR


BROWN
CLARK
CHAWLA
ANDERSON
RAMON
HUSBAND
MCCOOL
STS 107

Beautiful Fragile Blue Planet

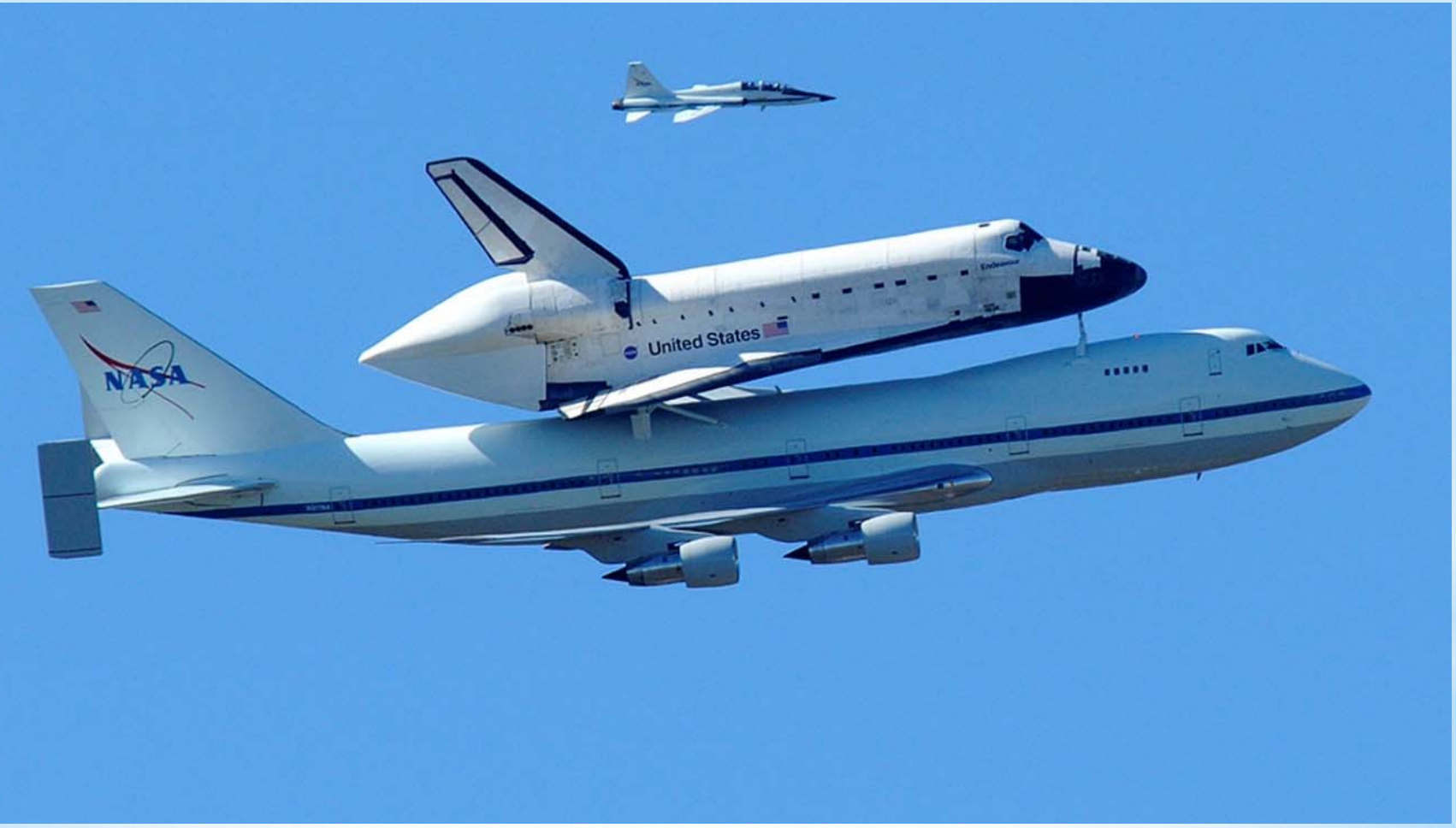

t in
hia.
Chicago
Cities of Boston, New York, Philadelphia and Washington.
Dallas
Houston
Miami
Puerto Rico

Earth at Night

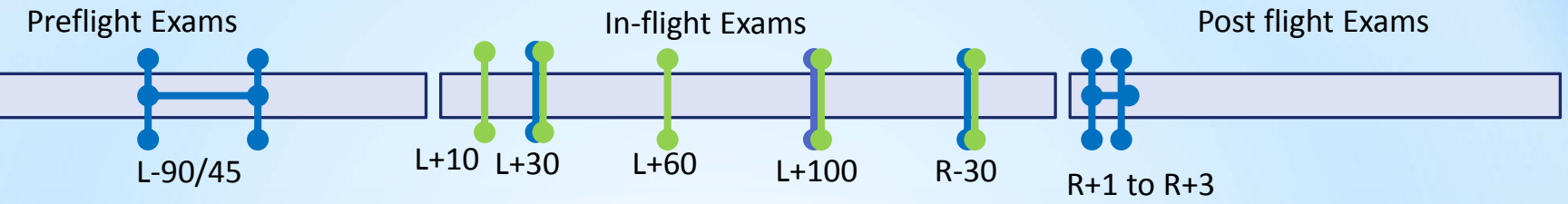


Guppy

T-38 and Guppy


NASA
United States

ntegrated Pre/In/Post-Flight VIIP Medical and Research Testing



able up
5 days

RI
nd Orbits
Contrast

L-90/45 days

- **Ultrasound** Eye/Orbit
- **Fundoscopy** - PanOptic Ophthalmoscope
- **Tonometry**
- **Visual Acuity** Including Amsler Grid Testing
- **Other Tests -** biomicroscopy (slit lamp), high resolution retinal photography, OCT (high resolution), and A-Scans

arch

L+30 & R-30,
L+100 <u>if requested</u>
(+/- 7 days) &
as clinically indicated

- **Ultrasound** Eye/Orbit
- **Fundoscopy** - PanOptic Ophthalmoscope
- **Tonometry**
- **Visual Acuity** Including Amsler Grid Testing

L+10, 30, 60, 100
& R-30,
(+/- 7 days)

- **Ultrasound** Eye/Orbit
- **Fundoscopy** - PanOptic Ophthalmoscope
- **Tonometry**
- **Visual Acuity** Including Amsler Grid Testing
- **Blood Pressure**
- **Vascular**

R+1 to R+3
(or as soon as possible)

- **MRI** Of Brain and Orbits Without Contrast
- **Ultrasound** Eye/Orbit
- **Fundoscopy** - PanOptic Ophthalmoscope
- **Tonometry**
- **Visual Acuity** Including Amsler Grid Testing
- **Other Tests -** biomicroscopy (slit lamp), high